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SCIENCE | TECHNOLOGY | HEALTH

THE POWER OF LAZINESS

WHY IT'S THE ULTIMATE EVOLUTIONARY STRATEGY

PLUS

WHY TAKING IT
EASY IS GOOD FOR
YOUR BRAIN, YOUR
BODY AND THE
PLANET



SLOWING DOWN CLIMATE CHANGE

How an Ice Age Jurassic Park could cool the planet

HAWKING'S LAST HURRAH

How his final words were beamed into a black hole

RETHINKING THE NEANDERTHALS

Why they weren't so different from us

MARTIAN DISCOVERY

Ingredients for life found beneath planet's surface



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MADE IN GREAT BRITAIN



Bees can count
→ p22

WHAT WE'VE FOUND OUT THIS MONTH

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→ p52



It's possible to get pregnant when you're already pregnant
→ p84



WELCOME



Laziness gets a bad rep. You see, I like to spend my time off occasionally embracing my inner loaf, but if someone asks me what I got up to at the weekend, I can't really admit that I spent the last 48 hours on my sofa, only moving for biological functions, while eating take-away pizza for breakfast and dinner. I'll admit it's not a pretty picture, but the problem is, the modern world batters you with the idea that you've got to do more 'stuff'. The kind of 'stuff' you can regale your colleagues with on Monday and bombard your friends with on social media. And the pressure is never higher than in the summer. So for those of you with bones as lazy as mine – here's a treat. This issue we give you a whole bunch of reasons to embrace your inner sloth. I can't be bothered to share them with you here, so turn to p38 to find out more.

Summer is also a time when the changing climate becomes hard to ignore. I have some good news and some bad news. The bad news is that some scientists think that the greenhouse effect is about to get much stronger. As the Siberian permafrosts becomes, well, less permanent, bacteria will start to feed on the matter buried beneath the ice, releasing millions of tonnes of CO₂ into the atmosphere. The good news is that a father and son have a plan, and it involves a mammoth, some bison and a tank... Find out what on Earth I'm talking about on p68.

Enjoy the issue!

Daniel Bennett

Daniel Bennett, Editor

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REBECCA WRANG
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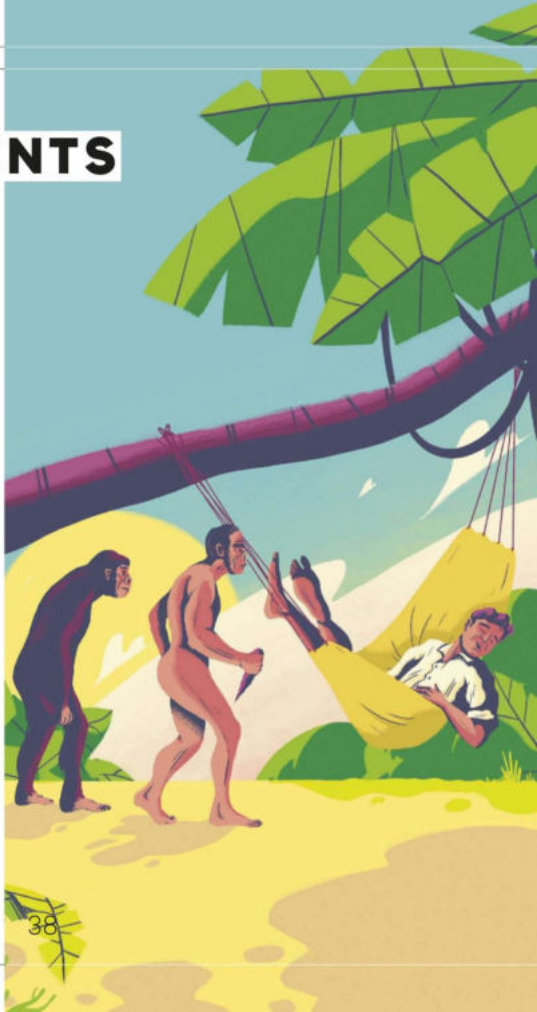
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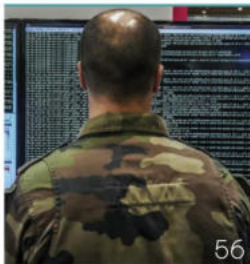
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SPECIAL ISSUE

ON
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SIMPLY EXPLAINED

In this special edition from BBC Focus, we investigate some weird science, such as wormholes, quantum physics, space-time and gravitational waves. buysubscriptions.com/focuscollection



EYE OPENER

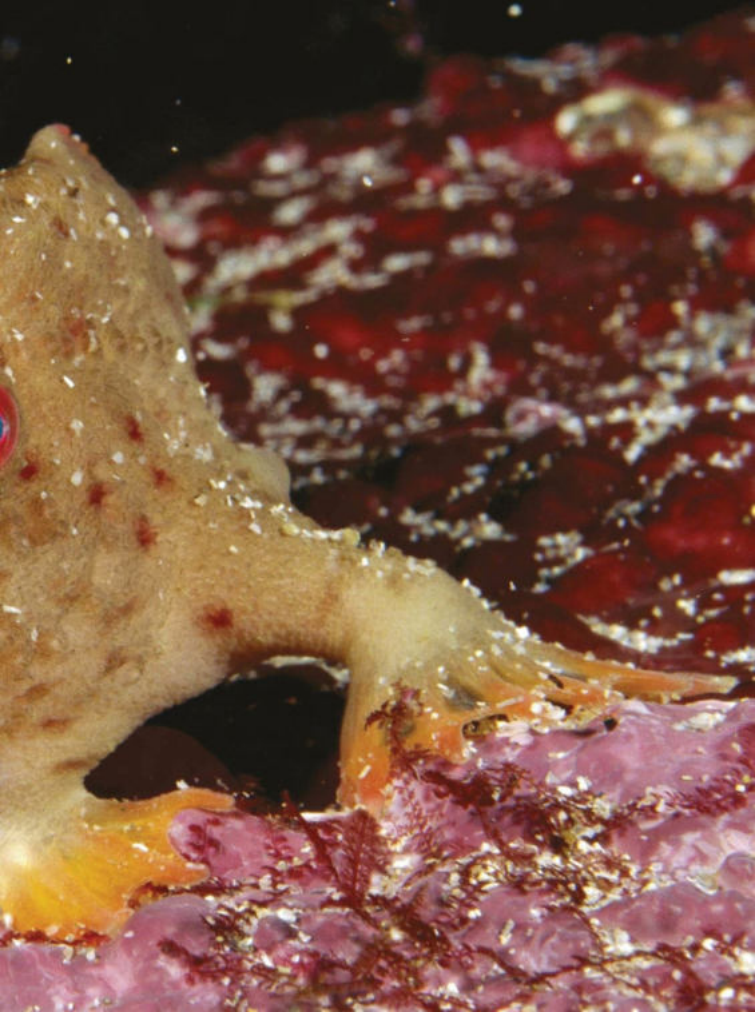
Fishy feet

TASMANIA,
AUSTRALIA

The red handfish, found off the southeast coast of Tasmania, uses its 'hands', which are modified fins, to crawl across the bottom of the seafloor. It doesn't travel very far or fast, which restricts populations to small areas.

Classed as critically endangered, it faces threats from habitat degradation and low reproductive rates. Often called the world's rarest fish, scientists only knew of one population, numbering between 20 and 40 fish, until divers discovered a second population earlier this year. "Finding this second population is a big relief as it essentially doubles the number of individuals we thought were left on Earth," says diver Antonia Cooper. "It provides hope that other small populations may still exist and allows scientists to start discussing conservation options such as habitat protection and the viability of a captive breeding program."

FRED BAYENDAM/PLR





EYE OPENER

Aviation impact

LOS ANGELES,
USA

Last year, a record 84 million passengers passed through Los Angeles International Airport, pictured here. That number is growing; the International Air Transport Association (IATA) predicts that global air passenger numbers will nearly double by 2036. This leads to concerns over aviation's contribution to global carbon emissions, as it's been estimated that 2 per cent of human-made CO₂ emissions currently come from air travel.

IATA aims to deliver carbon neutral growth from 2020, and provides an offset scheme in which member states can compensate for their emissions by financing a reduction elsewhere.

Individually, the Civil Aviation Authority advises the best way to reduce your CO₂ emissions from flying is to moderate your air travel where possible, choose more modern aircraft, purchase economy tickets and fly with airlines with lower CO₂ performance figures.

MIKE KELLEY



REPLY

Your opinions on science, technology and *BBC Focus*

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MESSAGE OF THE MONTH

Blind in the mind

At work recently a colleague was telling me how he discovered he had *aphantasia* after his cousin told him about the condition and “blew his mind”. Congenital *aphantasia* is a term that was coined in 2015 to describe people with little or no mind’s eye – meaning they can’t conjure up pictures or even sounds/music in their heads.

It was a revelation to me as well! I didn’t realise that people could ‘see’ and ‘hear’ things inside their own heads but after a lot of talk, and banter at my expense, I learnt that others can, and often experience it in a lot of detail.

I’d love to see an article about *aphantasia* in *BBC Focus* because it apparently affects 1 in 50 people and I struggle to understand what life is like for those with a good mind’s eye. Personally, my mind is generally description-based – I don’t see things so much as describe them to myself, and can only ‘hear’ music internally by humming the tune in my head.

Martyn Kilbryde, via email

Wow! Your letter’s caused a lot of head scratching in the office. And it’s raised a lot of questions – what appears if someone asks you to think of an elephant? Do you see the word instead of the animal? And what goes on in your head you’re reading fiction? It’s got us puzzled and wondering what, if any, consequences the condition entails. – *Daniel Bennett, editor*

WRITE IN AND WIN!

The writer of next issue’s *Message Of The Month* wins a **Yale Home View security camera**, which lets you see inside your home from a smartphone or tablet. Plus, you can remotely pan, tilt and zoom its viewpoint so you can keep an eye on things. If motion is detected, you’ll receive a notification, offering peace of mind when you’re off on your travels. yale.co.uk



The CO₂ generated in the manufacture of electric cars is offset by their lower emissions once they’re on the road

Batteries not included

Why did Jack Stewart’s otherwise excellent article on ‘How green are electric cars?’ (June, p87) not take into account the CO₂ emissions of building and recycling the vehicles, in addition to the emissions of running them? These should also be considered, especially in respect of the batteries.

Andrew Holt, via email

The construction of both electric and conventional cars has significant environmental impacts, and you could make a career out of quantifying them. Luckily for us, someone has: the Union of Concerned Scientists. In a 2015 analysis, they found that emissions from manufacturing cars with batteries can be 15 to 68 per cent higher than a gasoline car. However, that’s soon offset

when the cars hit the road, where lower emissions from motoring make up the deficit in 6 to 18 months. Responsibly reusing and recycling batteries for home energy storage, or to reclaim the cobalt, lithium and rare-earth metal ingredients, can help reduce the impact further. – *Jack Stewart*

Recollections reclaimed

Reading Philip Ball’s feature in July’s issue (July, p73) brought to mind one of my clearest

childhood memories of a camping holiday.

Everything had been packed away, except the tent in which my mother and I sheltered from the rain while my father went off in the car to collect something. He’d been gone a long time and we were getting worried when he and our car reappeared being towed into the site by a shire horse!



I've retold the story many times over the years but recently my mother pointed out that, although the event did happen, it occurred before I'd been born.

Initially, I found it impossible to believe such a clear memory could be false, but on reflection I realised I must be wrong because I had an elder brother who would have been there but was not part of my memory. I can only assume that I heard the story when I was young and at some later point my memory switched to make me part of the tale.

Geoff Dunwell, Maidenhead

Not so sweet dreams

With regard to the question 'Do babies have nightmares?' (June, p86), I believe they do. I had a repetitive one from as far back as I can remember. In the nightmare, I'd be lying down staring out of a stable door into inky blackness, then I'd be clutched all over by a piercing pain as if I'd been grabbed by pincers. The nightmares grew less frequent with age and after my mid-teens I never had it again.

Later in life my mother told me that my birth had been arduous and

Babies probably do have nightmares, says Roger Britton

forceps were needed to pull me from her womb. This chimed with what I was dreaming about and I believe I was recalling the moment of my birth in my sleep.

It's long been recognised that babies can hear while in the womb, but has anyone ever considered that they might also be developing an ability to perceive moments prior to their birth in some way? The fact that babies do such a lot of sleeping suggests that they might. If sleeping is a time for sensory absorption and mental organisation, it's no wonder they spend so much time in the land of nod.

Roger Britton, via email

Oops...

In the June issue (p79), it was wrongly stated that particles and antiparticles have opposite spin, and that this only has values of 1/2 or 1. They have the same spin, and its value can be zero, 1/2, 1 or multiples of these values, depending on the type of particle.

Also in the June issue (p17), a picture caption in a news story listed the Gaia mission as NASA. It is, of course, ESA.

BBC FOCUS

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DISCOVERIES

DISPATCHES FROM THE CUTTING EDGE

SUMMER 2018

EDITED BY JASON GOODYER

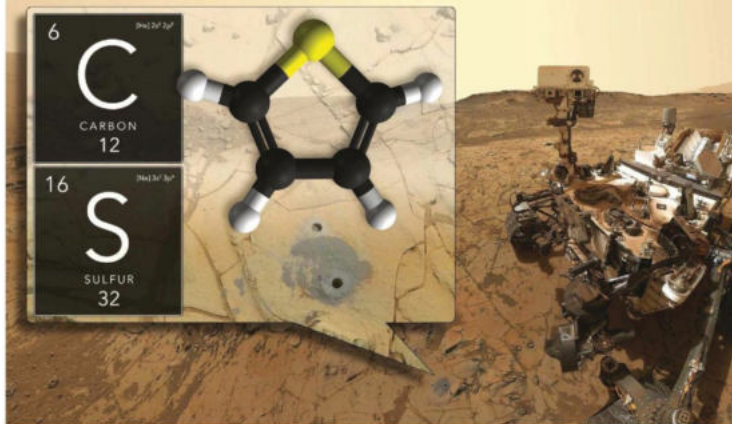
MARS

NASA FINDS COMPLEX ORGANIC MATTER IN MARTIAN ROCK

After years of scratching at the surface, the Curiosity Rover has uncovered what could be signs that life once existed on the Red Planet



NASA



Organic molecules found preserved in rocks on the surface of Mars have raised hopes that the Red Planet may once have been home to life.

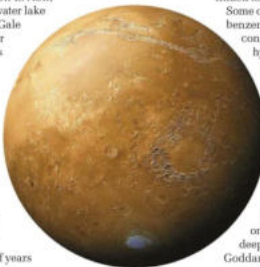
NASA's Curiosity Rover has found the most compelling evidence for the existence of life on Mars yet—complex organic molecules preserved in three-billion-year-old sedimentary rock.

Although the surface of Mars is inhospitable today, there's clear evidence that in the distant past the Martian climate was such that it allowed for the existence of pools of liquid water on the surface—an essential ingredient for life as we know it. Now, new data from Curiosity reveals that a water lake that existed billions of years ago inside Gale Crater held the ingredients necessary for life, including chemical building blocks and energy sources.

"With these new findings, Mars is telling us to stay the course and keep searching for evidence of life," said Thomas Zurbuchen, associate administrator of NASA's Science Mission Directorate. "I'm confident that our ongoing and planned missions will unlock even more breathtaking discoveries on the Red Planet."

Curiosity found the organic material by drilling into an area of sedimentary rocks, known as mudstone, on Mars's surface. This material formed billions of years

THE MOST COMPELLING EVIDENCE FOR LIFE ON MARS



ago as silt accumulated at the bottom of an ancient lake. The rock samples were then analysed using Curiosity's Sample Analysis at Mars instrument, which uses an oven to heat samples to 500°C to release any organic molecules trapped within.

All organic compounds contain carbon—a key component of all known life on Earth. Key to this is carbon atoms' unique ability to link together to form long chains, allowing them to create millions of compounds with different properties. For example, our own DNA is made up of many carbon chains linked together and twisted into a double helix.

Some of the molecules identified include benzene, an important constituent of crude oil consisting of six carbon atoms and six hydrogen atoms, and propane, a natural gas made from three carbon atoms linked to eight hydrogen atoms used in everything from heaters to barbecues.

If these simple compounds were able to form on the planet's surface it means it is also possible that more complex compounds, and maybe even life, were able to form too, the researchers say.

"Finding ancient organic molecules in the rock that was deposited when Mars may have been habitable, bodes well for us to learn the story of organic molecules on Mars with future missions that will drill deeper," said Jen Eigenbrode of NASA's Goddard Space Flight Center.



ABOVE: The Curiosity Rover found carbon-based organic molecules, indicative of life, after drilling into the Martian surface

LEFT: Conditions on Mars were thought to be suitable for liquid water in the past

GENETICS

MALE MICE TURNED INTO FEMALES USING DNA PREVIOUSLY THOUGHT TO BE 'JUNK'



"Hang on, I think something might be missing." Scientists tweak genes to turn Mickey into Minnie

Snipping out a small region of DNA previously considered to be 'junk' leads to male mice developing ovaries instead of testes, researchers at the Francis Crick Institute have found. The finding could lead to treatments for sexual development disorders in humans, they say.

During their early development, mammals develop ovaries and become female unless they have a certain amount of a protein known as SOX9 in their developing gonads. SOX9 causes these organs to become testes, which subsequently direct the remainder of the embryo to become male.

The team found that snipping out a small piece of DNA called Enhancer 13 (Enh13) shut off the production of SOX9 in male mice with XY chromosomes, leading to them developing ovaries.

The amount of SOX9 produced is controlled by a gene called Sry, which is located within the DNA that makes up the Y chromosome. This is why males, who have an X chromosome and a Y chromosome,

usually develop testes while females, who have two X chromosomes, do not.

Just 2 per cent of human DNA contains the 'code' to produce proteins – the key building blocks of life. The remaining 98 per cent is known as 'non-coding' and was once thought to be unnecessary 'junk' DNA, but there is increasing evidence that this is not the case.

Experiments leading to sex reversal in mice have been going on for decades. In 1991, a different team of scientists bred Randy, a chromosomally female (XX) mouse who developed into a male after the team introduced the Sry gene into the developing embryo.

"We've come a long way since Randy and now, for the first time, we've demonstrated sex reversal after changing a non-coding region of DNA rather than a protein-coding gene," said Prof Robin Lovell-Badge, who leads the research team. "We think Enh13 is probably relevant to human disorders of sex development and could potentially be used to help diagnose some of these cases."

ANTHROPOLOGY

INCAN SURGEONS WERE SURPRISINGLY SKILLED AT DRILLING HOLES IN PEOPLE'S SKULLS



Thankfully, trepanation – the act of scraping, cutting, or drilling an opening into a person's cranium to treat everything from headaches, to seizures, or even supposed demonic possession – is a practice largely confined to the past. But if you were ever in need of such an operation, you could do a lot worse than seeking out an Incan surgeon.

After analysing 800 ancient skulls found in Peru that had undergone trepanation, a team at the University of Miami found that the procedures were carried out so expertly that the survival rate was more than 75 per cent – almost double that of those who underwent similar procedures during the American Civil War hundreds of years later. “In Incan times, the mortality rate was between 17 and 25 per cent, and during the Civil War, it was between 46 and 56 per cent. That’s a big difference,” said Dr David S Kushner, who led the research. “The question is, how did the ancient Peruvian surgeons have outcomes that far surpassed those of surgeons during the American Civil War?”

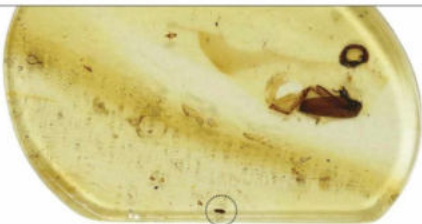
Researchers say the poor hygiene practices

seen during the Civil War may have been a contributing factor, but little is known about exactly how the Peruvian surgeons performed the operations.

It is thought that hygiene, or more accurately the lack of it, during the Civil War, may have contributed to the higher mortality rates in the later time period. According to the study, which relied on co-author John W Verano's extensive field research on trepanation over a nearly 2,000-year period in Peru and a review of the scientific literature about trepanation around the world, Civil War surgeons often used unsterilised medical tools and their bare fingers to prise open cranial wounds or break up blood clots.

“We do not know how the ancient Peruvians prevented infection, but it seems that they did a good job of it,” said Kushner. “Neither do we know what they used as anaesthesia, but since there were so many (cranial surgeries) they must have used something – possibly coca leaves. Maybe there was something else, maybe a fermented beverage. There are no written records, so we just don’t know.”

Evidence of trepanation can be seen on these ancient Peruvian skulls. If the bone around the surgical hole shows no signs of healing, researchers know the patient died either during or shortly after the surgery



You can just about see the feathery wings of this fossilised beetle in the bottom image



PALAEONTOLOGY

THIS TINY BEETLE HAS BEEN STUCK IN AMBER FOR 99 MILLION YEARS

Forget John, Paul, George and Ringo, our favourite beetle is named Jason, or *Kekkeus jason*. Dr Shuhei Yamamoto discovered a tiny featherwing beetle trapped in amber while poring over the archives at the Field Museum in Chicago. Amber is made from fossilised resin, a sap-like substance made by plants. When prehistoric animals got trapped in the resin, their bodies would get incorporated into it as it hardened, preserving them perfectly for years – in this case 99 million years.

"I didn't have much confidence at first, but after cutting and polishing the amber so I could get a better look, I realised, 'oh, this is truly an amazing fossil,'" said Yamamoto.

Measuring less than half a millimetre, the tiny beetles take their name from the feathery

fringe found on their wings that enables them to catch the air and float like dandelion seeds. The team named their find after the Greek hero who sailed the world in search of the Golden Fleece.

By looking at the beetle through a microscope, Yamamoto noticed that its body was preserved in fine detail, and he could see a series of three grooves running like pinstripes up its body. This feature is not found in its modern cousins, meaning the insect belonged to a different species and genus from living featherwing beetles.

"This tiny beetle lived during the Cretaceous Period, it saw actual dinosaurs," said Yamamoto. "The amber the beetle was found in is like a time capsule."

IN NUMBERS

103 BPM

The ideal rate for performing chest compressions when administering CPR, as found by a team at the University of Barcelona. It also happens to be the tempo of the chorus in the pop song *Macarena*, they say.

546 MILLION YEARS

The age of a set of footprints made by an unknown animal in Southern China – the oldest of any found to date.

6 HOURS

The length of time days on Earth have increased in the last 1.4 billion years, thanks to the fact that the Moon is gradually moving away from us. This happens as the relative position of the Moon affects the rotational speed of the Earth, much as the arms of a spinning figure skater affects their speed.

BIOLOGY

"Dolphins are phenomenally good at using echolocation, much better than man-made devices"

Dolphins echolocate with two-part acoustic beams. Dr Josefin Starkhammar of Lund University explains how this could help us improve ultrasound technology

ABOVE: Dolphins use echolocation to determine where they, the rest of their pod and any potential prey are in the water

Why do dolphins need echolocation?

They use it for navigation, hunting for prey and possibly in social contexts. Dolphins always use acoustics as their primary sense. They generate short sound pulses, which bounce off surfaces and come back as echoes – the time it takes to return is a measure of how far away an object is. The beam is quite focused so the dolphins turn their heads to scan their environment.

How do they produce acoustic beams?

They have a structure below the blowhole called the phonic lips. Sounds come out through the melon, the rounded forehead – it's one of the tissues responsible for the shape and formation of the beam. It's basically an acoustic lens: the speed of sound is faster along the edges compared to the core of the melon, so the beam ends up cone-shaped. Dolphins have extremely short signals, usually much shorter than bats.

How did you study dolphin signals?

You need one dolphin echolocating in a specific direction and hydrophones – microphones for underwater use. I built my measurement system

as a PhD student with 47 hydrophones. If we use all of them and record the cross-section of the beam, we can see finer details. I wanted to learn more about how they use these small details to solve tasks, because dolphins are phenomenally good at using echolocation, much better than man-made devices. I was looking at the signals and realised that regular methods couldn't give me the information, so I talked with colleagues working with mathematical statistics and we developed a signal-processing algorithm that helps us look at signals in a much more detailed way.

What did you discover about the beam?

Even though the signal from the dolphins is very short, about 70 microseconds long, my previous research found that it actually consists of two intertwined beam components. The algorithm helped us decipher this, and we've discovered that parts of the beam consist of overlapping pulses. You get two slightly time-separated echoes from the upper part of the beam first as a low-pitched note and then a high-pitched one. From the lower part of the beam, you only hear a low-pitched echo. Dolphins have a frequency gradient across the beam, so in theory they could use this



BELOW: Dolphins produce acoustic waves and focus the sound with their melons (yellow). Sound waves reflected by objects are channelled to the auditory bulla (orange), which transmits the nerve signals to the brain



DIGESTED READ

Dolphins' echolocation has evolved over millennia to become a far more sophisticated system than anything we can design and build. By studying the mammals it's hoped we can find ways to improve our own ultrasound technology.

information to locate objects more precisely; if prey is moving upwards in the beam, the pitch will get higher and higher in frequency.

What are the practical applications?

With the algorithm, we hope it can be applicable to non-destructive testing methods for diagnostics, such as if we want to measure the thickness of a very thin layer in the body. So improved image resolution. The other aspect is what we can learn from dolphins. For instance, the concept of using two intertwined sound beams with a frequency gradient cross-section might improve ultrasound machine performance. We could also make boat sonars more effective by employing these principles. After all, millions of years of evolution have formed dolphin echolocation to perfection, so there are definitely things we can learn from them.



GLASSES WEARERS

It seems people who wear glasses really are smarter than average. A study of the genetic data of 300,000 people has found that those who scored the highest in intelligence tests were 30 per cent more likely to have genes that suggest they need to wear glasses.

COFFEE DRINKERS

Want to boost the effectiveness of your team? Have a cup of Joe. Researchers at Ohio State University found that drinking a cup of coffee before a group activity made participants more talkative, more positive and more engaged when carrying it out.

GOOD MONTH

BAD MONTH

DIRTY FOOTBALLERS

Football referees are more likely to show players red or yellow cards for foul play they've watched as a slow-motion replay, researchers at the University of Leuven have found. The effect may be due to fouls appearing to last longer and occur more violently when played in slow motion.

PHOTOGRAPHERS

If you want to remember something, don't take a picture. Taking a snap of something impairs our ability to recall it later, researchers at the University of California have found. It's unclear why but it may be due to us paying less attention to an experience when we know it'll be safely stored, they say.



TRENDING

Your guide to the hottest topics in the world right now

#MICROBIOME

MICROBES HELP SOLVE CRIMES

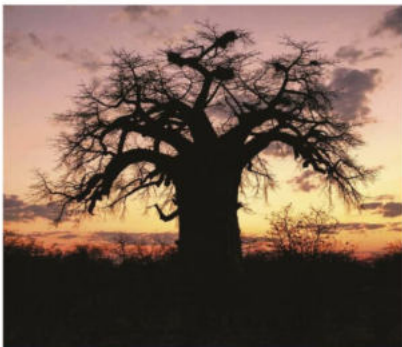
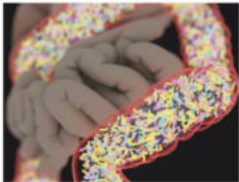
Researchers in Atlanta 'solved' staged crimes by analysing microbial signatures at the scene. The team collected samples from residents' and non-residents' nostrils and hands, and various surfaces in the residents' homes prior to and following mock burglaries by non-residents. They then identified the bacteria belonging to each individual to pinpoint the perpetrators with an accuracy of 60 per cent.

GUT BACTERIA INFLUENCE LIFESPAN

The bacteria living in our intestines could have an influence on how well we age. Researchers at McGill University prolonged the life of fruit flies by 60 per cent by feeding them with a combination of probiotics and a herbal supplement called Triphala.

HEALTHY MICROBIOME = HEALTHY ARTERIES

Low diversity of the 'good bacteria' in our digestive systems is linked to the hardening of the arteries in cardiovascular disease, according to researchers at the University of Nottingham and King's College London. Targeting the microbiome through diet, medication and probiotics could therefore be a way to reduce cardiovascular disease risk.



#CLIMATE CHANGE

HOTTING UP

A draft report from the UN's Intergovernmental Panel on Climate Change (IPCC) leaked to Reuters states that human-induced global warming will exceed 1.5°C in the next 20 years if emissions continue as they are.

FRIED FISH

Climate change is forcing fish to change habitats faster than the world's system for allocating fish stocks can keep up, exacerbating international fisheries conflicts, researchers at Rutgers University

say. Many commercially valuable fish species could move their ranges hundreds of miles north in search of cooler waters.

BYE BYE, BAOBAB?

Over the last 12 years, a number of ancient baobabs – iconic African trees that live for thousands of years and grow to 30m tall – have died, leading to calls for better conservation efforts. Romanian researchers report that 9 of the 13 oldest trees that they have been studying have died. Most likely culprit? Climate change.

#PLASTICS

PLASTIC ANTARCTIC

A three-month study carried out by Greenpeace has found microplastics and toxic chemicals in snow and water samples taken from Antarctica, meaning that plastic is now found in all the Earth's oceans.

SO LONG, STRAWS

McDonald's will be replacing plastic straws with paper ones in all of its UK outlets starting from September. Its restaurants currently get through 1.8 million straws a day in the UK alone.

RECYCLED TARGETS

According to the Green Alliance, if we recycled all our plastic waste within the UK we could meet nearly three-quarters of domestic demand for plastic used in manufacturing and packaging. In the UK we consume over three million tonnes of plastic a year, but more than 60 per cent of this is recycled abroad – just 10 per cent is recycled domestically.



#SLEEP

DEPRESSION RISK

Early birds are less prone to depression, according to researchers at the University of Colorado. A four-year study involving more than 30,000 student nurses has found that early risers are up to 30 per cent less likely to suffer from depression than night owls. Specific genes that play a role in sleep patterns are also associated with depression risk, they say.

REST TO AVOID ALZHEIMER'S

Losing just one night of sleep led to an immediate increase in beta-amyloid, a protein associated with Alzheimer's disease, a study at the National Institutes of Health has found. In Alzheimer's disease, beta-amyloid, a metabolic waste product present in the fluid between brain cells, clumps together to form plaques that negatively affect communication between neurons.





Scientists don't yet recommend this to humans

NEUROSCIENCE

PSYCHEDELIC DRUGS MAY RESTRUCTURE THE BRAIN

Psychedelic drugs, such as LSD, DMT and DOI, really can expand your mind... as long as you're a rat or a fly. A study of the drugs' effects on the rodents and insects showed neurons in their brains were more likely to branch out and make new connections.

If the drugs have a similar effect on human brains, it's thought they may have potential as a treatment for depression, anxiety, addiction and even post-traumatic stress disorder (PTSD).

"These are some of the most powerful compounds known to affect brain function. It's very obvious to me that we should understand how they work," said the paper's senior author Dr David Olson, of the University of California, Davis.

Depression is widely believed to be a result of imbalanced brain chemistry, but recent research points

to the condition manifesting as structural changes in the brain. "One of the hallmarks of depression is that neurites [the 'branches' on the ends of neurons] in the prefrontal cortex – a key brain region that regulates emotion, mood and anxiety – tend to shrivel up," said Olson. This shrivelling also appears in cases of anxiety, addiction and PTSD, and the further the neurites retract, the harder it becomes for brain signals to bridge the gaps between synapses. But the use of psychedelics increased both the density of neurites and the density of synapses.

Olson's team doesn't yet know if the drugs will do the same in human brains. But the similar effects observed across the rat and fly test subjects suggest the biological mechanisms that respond to psychedelics haven't deviated during the two species' evolution.

THEY DID WHAT?!

MATHS TAUGHT TO BEES

What did they do?

Researchers at the University of Melbourne, Australia, trained two groups of bees to fly to a wall where two white panels containing different numbers of black shapes were displayed. Using food rewards, they then taught half of them to travel to the 'less than' panel and half to travel to the 'greater than' panel.

What did they find?

The bees quickly learned to fly to the correct location, even when one of the panels had no black shapes on it at all. This suggests they are able to understand the concept of zero.

Why did they do that?

It may seem to be intuitive to us humans, but the ability to understand the mathematical concept of zero is rare elsewhere in the animal kingdom – only dolphins, parrots and primates have passed the test. In fact, the ability only arose in humans around 500 AD in India. The findings have far-ranging applications, particularly in the development of artificial intelligence, according to the researchers.



BEETLE ILLUSTRATION BY JIM WALLING



HAWKING'S LAST HURRAH

*The world famous physicist and author of A Brief History
Of Time is laid to rest alongside Newton and Darwin*



Hawking's ashes are interred, watched over by his family and the Dean of Westminster (third from right)

No one since Einstein has done more to deepen our knowledge of the cosmos and inspire achievement against the odds."

Those were the words Lord Martin Rees, the Astronomer Royal, used to describe his friend, colleague and fellow scientist Prof Stephen Hawking at his memorial service on Friday 15 June. Hawking, the physicist renowned for unravelling the mysteries of black holes and his distinctive synthesised voice, was laid to rest in a special ceremony held at Westminster Abbey in London.

Before his death on 14 March 2018, aged 76, Hawking had garnered an unprecedented level of global recognition for his scientific discoveries and ability to popularise them. But his achievements were perhaps all the more notable since they came in the face of an almost life-long struggle with motor neurone disease – a degenerative condition that robbed Hawking of his ability to walk and talk.

Often characterised as a man whose body was trapped in a wheelchair but whose mind was free to wander among the stars, his final farewell reflected the contrasting nature of Hawking's existence. As his ashes were interred in the ground of Westminster Abbey between those of Isaac Newton and Charles Darwin, an audio recording of Hawking reading a tribute, set to music by the composer Vangelis, was beamed into space towards 1A 0620-00 – the nearest black hole to Earth.

While his funeral, held on 31 March,

was an understandably solemn affair, the memorial service was a colourful celebration of Hawking's life and work. It began with Westminster Abbey's organist playing *Venus, The Bringer Of Peace* from Holst's *The Planets*, and was later brought to a close with Wagner's *Ride Of The Valkyries*.

Leading the ceremony was the Dean of Westminster, the Very Reverend Dr John Hall, who used his opening bidding to allude to the dilemma of remembering,

"ONE OF THE GREAT REVELATIONS OF THE SPACE AGE HAS BEEN A PERSPECTIVE IT HAS GIVEN HUMANITY ON OURSELVES"

celebrating and burying a scientist in a place of religious worship.

"We come to celebrate the life and achievements of Stephen Hawking in this holy place where God has been worshipped for over a thousand years, and where kings and queens and the great men and women of our national history and international influence are memorialised."

Rees also attempted to answer the questions raised by the occasion in his address, pointing out that although the physicist shared an agnosticism similar to that of Darwin's, Hawking himself described his scientific quest as a mission "to learn the mind of God."

But it was Hawking's friend, the physicist and Nobel Laureate Kip Thorne, who perhaps provided the best solution while speaking at the ceremony: "[Stephen] earned a special place in the hearts of admirers worldwide and a special place in Westminster Abbey, beside Isaac Newton."

Thorne also described Hawking as "the most stubborn friend I had. He absolutely refused to let his condition get in the way of doing great work and having great fun... He was someone whose love for life was legendary and whose courage and creativity were inspirational."

While Hawking's scientific insights earned him respect, and his perseverance in the face of physical adversity won him admiration, it was perhaps his mischievous sense of fun that helped him become such a popular figure all around the world.

The many people that came to his memorial service from all walks of life were testament to that. As well as his family and friends, Westminster Abbey was filled with fellow eminent scientists, the astronomer Colonel Chris Hadfield and Major Tim Peake, the actor Benedict Cumberbatch and hundreds of schoolchildren. People with motor



Astronomer Royal Lord Martin Rees



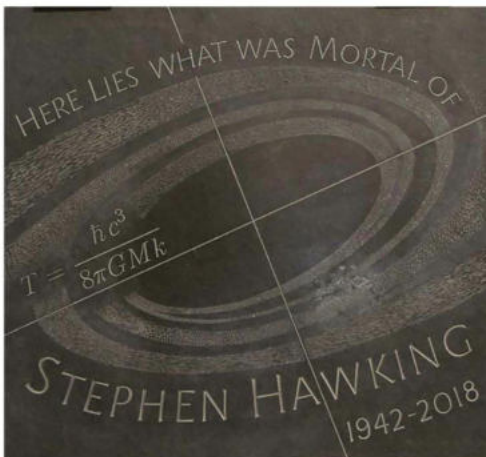
Hawking's children Lucy and Timothy arrive at Westminster

neurode disease and other conditions that confined them to wheelchairs also came, as did a Marilyn Monroe lookalike (Hawking was reputedly a big fan of the Hollywood star). But as far as anyone is aware, no time travellers were present, despite there being an open invitation to anyone from the future with the capability to attend.

While his crowning scientific achievement may have been the discovery of Hawking radiation, it was his ability to build bridges that is perhaps his greatest legacy – bridges between Einstein's General Theory of Relativity and quantum theory, bridges between academia and the general public, bridges between scientific insight and social responsibility and, once again, as his tribute message was beamed out into the stars, a bridge between Earth and space.

As Thorne said in his address, "We remember Newton for the answers he gave us. We remember Hawking for the questions with which he challenged us."

It was perhaps fitting then that Hawking used his final tribute to pose some of the biggest questions, while also hinting at how we might find an answer: "How will we feed an ever-growing population, provide clean water, generate renewable energy, prevent and cure disease and slow down global climate change? I hope that science and technology will provide the answers to these questions but it will take people, human beings with knowledge and understanding, to implement the solution. One of the great revelations of the space age has been a perspective it has given humanity on ourselves." ●



Memorial stone (above) placed on top of Stephen Hawking's final resting place (below)



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"COULD DIFFERENT MEALTIMES MAKE YOU HEALTHIER?"



DR MICHAEL MOSLEY

EMILY TWO Michael is a science writer and broadcaster, who presents *Trust Me, I'm A Doctor* on BBC Two. His latest book is *The Clever Guts Diet* (£8.99, Short Books).



Six years ago, during the London Olympics, a documentary I'd made, *Eat, Fast, Live Longer* went out on BBC Two. It was up against the 200m finals, featuring Usain Bolt, so I wasn't optimistic that it would be a ratings success. It actually did better than I was expecting and in time, unleashed huge interest in intermittent fasting, IF. The idea behind IF is that you can lose weight and get other health benefits by intermittently cutting your calories.

At the time I was investigating the benefits of cutting calories a couple of days a week, as part of the 5:2 diet. But there are other forms of IF, including Time Restricted Feeding (TRF). TRF normally involves eating within an 8-hour window and fasting for 16 hours a day. But what is the evidence that this is healthier than normal patterns of eating?

The 16:8 approach is based largely on the work done by Prof Satchin Panda from the Salk Institute. In a 2014 study, he and other researchers subjected hundreds of mice to different lengths of daily fasts, ranging from 12 to 15 hours. They found that the benefits

were proportional to the length of the fast, but as long as the mice went at least 12 hours without eating they remained healthier and slimmer than those who ate the same number of calories spread out. What was surprising was the protective effects were maintained, even when the mice were allowed unlimited access to food during weekends.

All this is great if you are a mouse, but how well does TRF work in us? There have been surprisingly few human studies, though the ones that have been done are generally positive. There was, for example, a small study carried out by the University of Alabama where 11 overweight people were asked to spend four days eating between 8am and 2pm and four days eating between 8am and 8pm. They ate the same number of calories both times and completed testing under supervision. The researchers found that eating only between 8am and 2pm reduced daily hunger swings and increased fat burning during the night. It also improved metabolic flexibility,

which is the body's ability to switch between burning carbs and fats. Crucially, it didn't lead to weight loss.

On *Trust Me, I'm A Doctor*, we decided to test TRF. With the help of Dr Jonathan Johnston at the University of Surrey, we recruited 16 volunteers and randomly assigned them to one of two groups, the blues or the reds.

The blues, the control group, were asked to carry on as normal. The reds were asked to stick to their normal diet but move their breakfast 90 minutes later, and dinner 90 minutes earlier. This meant that for three extra hours each day they went without food. Everyone kept a food and sleep diary to ensure that they were eating the same amount as normal. After 10 weeks we found that the group who had eaten breakfast later and dinner earlier had, on average, lost a bit more body fat and seen significant falls in blood sugar levels and cholesterol levels, compared to the control group.

This was a small study and it didn't run for long. But there do seem to be some benefits of extending your daily 'fast' – and it is a good idea to avoid the midnight cheeseburger. **Q**

Prof Satchin Panda's book is *The Circular Code: Lose Weight, Supercharge Your Energy And Sleep Well Every Night* (USA:99, Veritas).



UNHCR
The UN Refugee Agency

URGENT

MONSOON DEFENCE APPEAL

Humaira and her children have already lost so much. Now they stand to lose even more.

With the start of the monsoon season, Humaira and her children's lives and home could be washed away in an instant by floods and mudslides. If they survive, they will be at risk of deadly waterborne diseases like cholera and diphtheria.

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£75

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INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

SUMMER 2018

EDITED BY HELEN GLENNY



FLYING SOLO

Here's one for the Christmas list: a lightweight, single-person drone plane that you can pilot yourself after just a few hours of training.

The 'Flyer', which has been created by the start-up company Kitty Hawk, has 10 battery-powered propellers and weighs 11.3kg. The pilot has two controls: a joystick for direction, and a slider for speed, with no other instruments or screens. An onboard computer takes care of the tough job: keeping the Flyer level.

In the US, the Flyer falls into the Federal Aviation Authority's ultralight category, which means it can be flown without a pilot's licence,

but only in uncontrolled airspace (typically away from people and planes). Kitty Hawk, which was set up by Google co-founder Larry Page, has so far stuck to testing its flying car prototypes over Nevada's Lake Las Vegas.

With a maximum elevation of three metres and a top speed of 32km/h (20mph), the current Flyer has limited use as a form of transport, especially as the battery can only power 20 minutes of flight at a time. But with companies like Uber and Airbus also working on flying car projects, we can be sure these hurdles won't stand in the way for long.



WANTED

1 HANDS-FREE KIT

Sonos's new soundbar ditches the remote for Alexa compatibility. This means you can control the Beam and smart gadgets in the house using voice commands and tell it what TV you want to watch if you use it with an Amazon Fire TV stick.

Sonos Beam
£399, sonos.com

2 FLY HIGH

Built for aerial photography and videography, the Anafi has a range of 3.2km and a 25-minute flight time, with a camera that shoots in 4K HDR. It folds up for easy transport – perfect for slipping into your hiking rucksack.

Parrot Anafi
£649, anafi.parrot.com

3 SMELL THE ROSES

Wake up to the smell of a meadow, a fresh cappuccino or a bunch of roses with this multisensory alarm clock. First, it pumps out smells, followed by light, then gentle sounds. It'll make your smartphone alarm sound like a jackhammer.

Sensorwake
\$59 (about £44), trio.sensorwake.com

4 TOUGHEN UP

Don't worry about buying an action camera, get a really rugged smartphone instead. This 4G device measures just 96 x 45 x 18mm and can take 16MP photos and film underwater. It even has a fingerprint sensor and NFC capabilities.

Unihertz Atom
\$219 (approx £164), bit.ly/atom_phone

5 OLD-SCHOOL COOL

Get in line, arcade fans – this wall-mounted console is hand-crafted from wood and pays homage to the original Pong cabinet. It's stuffed with nostalgic games like *Paperboy* and *Battletoads* that you can play at home on modern hardware.

Origin X
£2,899 (approx £2,560), lovehulten.com

6 GET FIT, LOOK SHARP

Garmin's new GPS watch brings together a great set of features: 500-song storage, advanced sleep-tracking, preloaded workouts, contactless payments and seven hours of battery life, all for a reasonable price too.

Garmin Vivoactive 3 Music
\$300 (approx £225), garmin.com

GAME ON

Serious gaming is going mobile, with big multiplayer titles like *Fortnite* and *PlayerUnknown's Battlegrounds* (commonly known as *PUBG*) steaming to the top of app store charts this summer. It seems logical then that smartphone manufacturers are finally getting serious about gaming. The strongest entry we've seen so far is the ROG phone, from gaming giant Asus, which has been under development since 2013 and will be available later this year.

Design-wise, it looks more like a gaming console than a traditional smartphone, with a dark shell and customisable Aura RGB lights. Using the fastest version of the Qualcomm Snapdragon 845 processor and with a standard 8GB of RAM, the ROG phone has more power than some laptops. Heat is clearly an issue, so the phone has its own GameCool 3D vapour-chamber cooling system and a copper heat spreader to keep things running smoothly. It also comes with an AeroActive cooler, which clips onto the phone, adding a fan, an extra headphone jack and USB-C port for peripherals.

It has a six-inch full HD+ display and weighs a hefty 200g, but for anyone interested in gaming on the go, the size and weight look like a worthy trade-off.

Asus ROG phone
ETBC.asus.com

7





ARTIFICIAL INTELLIGENCE

COULD ALGORITHMS HELP DETECT VIOLENCE?

Drones may one day hover over crowds in public spaces and at large events, scanning for signs of violent behaviour, according to a team of researchers from the UK and India.

The researchers developed a computer algorithm that maps human postures and attempts to match them to 'violent' archetypes: strangling, punching, kicking, shooting and stabbing. The team then trained this algorithm on recorded footage of fake fights and once it had become accurate they tested out on a live video of a group of actors to see whether the tech would work in real-time. The accuracy of the system wasn't perfect. The researchers reported 94 per cent accuracy when it came to identifying 'violent' poses, which dropped depending on how

many people were in the frame. More importantly, this new technology was tested on between 2 and 10 volunteers generously spaced apart who were clearly pretending to attack one another – not exactly a real-world situation. The researchers plan to further test the software at two upcoming festivals in India.

Both Google and Facebook have published studies showing that neural networks can be used to track poses, but it's hard to imagine the technology being deployed soon. The images the system analysed were taken from between two and eight metres away, and given how loud drones are, festival goers probably won't appreciate the noise, even if it is keeping them safe.

The algorithm was accurate at spotting violent behaviour (inset), and could be useful for keeping people safe in a crowd (main image)

GLOBAL WARMING

AFFORDABLE CARBON CAPTURE TECHNOLOGY IS ON ITS WAY

Sucking carbon dioxide from the air was long touted as far too expensive to be realistic, but a new cost analysis is changing that idea. The study, published in the journal *Joule*, estimates that carbon capture could now cost between \$94 and \$232 per tonne of captured carbon dioxide. Previously, the technology was estimated to cost around \$1,000 per ton.

What's more, the cheapest design outlined by the study involves using that captured CO₂ to make carbon-neutral fuels that can be sold.

The technology uses fans to draw ambient air through a liquid that reacts with CO₂, which is then processed to create a purified

stream of CO₂ gas. The CO₂ is then combined with hydrogen to make fuels.

Most of the tweaks that have reduced the cost of this direct-air carbon capture relate to the design of the system. They include using structures that are stacked horizontally rather than vertically, which are cheaper to build, and less expensive power sources to run the plant.

A number of studies have found that without some form of carbon capture technology, it's unlikely that we'll be able to rein in global warming to within 2°C of pre-industrial levels.



This demonstration plant in British Columbia captures carbon dioxide from the air

GETTY/CARBON ENGINEERING, NISSAN, SPOTMINI

TECH BYTES



CANINE PAL

SpotMini, Boston Dynamics' smooth-moving robot dog, will go on sale next year. It's marketed as a security or surveillance patrol, but we just want a non-barking, non-pooping fetch friend.



PITCH PAINTER

Nissan's Pitch-R can mark out professional-standard football pitches wherever there's space, on grass, tarmac, or even gravel. Uneven ground is no problem, as the Pitch-R can navigate obstacles.

DRONE POLLINATION

A hexacopter has pollinated two hectares of apple trees in an effort to improve yields. It could also be used on cold spring days when bees aren't active – low bee activity can lead to poor growing seasons.

DEEP LEARNING

NEW AI CAN SEE THROUGH WALLS



It's the X-ray vision that sci-fi films have always promised us: new technology can now detect people through walls, and project them as colourful, weirdly-accurate stick figures.

A team of researchers at MIT have trained a neural network to throw Wi-Fi through walls, where it bounces off any people on the other side. The system then analyses the patterns as they return to the source.

Previous technology has only been able to construct blobs indicating people's locations. This new system can identify 14 different key points on the body, including the head, elbows and knees, and construct dynamic skeletons of the person, their posture, and their movement.

The team's main goal is to use this new technology to monitor and track the movements of people with neurodegenerative diseases in their day-to-day lives, and they're already taking steps to anonymise and encrypt any detected data.



SOCIAL MEDIA

Eye-opening algorithm in Photoshop (column 3) blends two images of the subject (column 1 and 2). Facebook's proposed technique (column 4)

FACEBOOK CAN OPEN YOUR EYES

New technology from Facebook can replace closed eyes with convincing open ones, ringing in the end of untimely blinks ruining your group shots.

It's called 'in-painting', and it's not new: software like Photoshop has the ability to fill in space with what the program thinks should be there – imagine removing a tree and filling the gap with the same blue sky that surrounded that tree.

But eyes are a big leap forward. Facebook points out that we're extremely sensitive to small errors in facial structure, especially on our own faces, or those of the people we know well. Then there's the 'uncanny valley' effect: the feeling of eeriness or revulsion we get when we see a humanoid object that isn't quite right.

Eye 'in-painting' could already recognise and reconstruct convincing eyes, but it didn't always maintain consistency with the rest of the image. Facebook improved the process by including other photos of the target person with their eyes open, so as well as learning which eyes should go on that person, they learn about the ways the eyes are shaped and coloured.

The results are impressive. In testing, people mistook the fake eyes for the real ones or couldn't tell the difference more than half the time. It's hard to imagine users being able to spot the fakes if they scrolled past them in their newsfeed. Like a lot of new tech, it's a tad creepy; but if it ends the constant re-taking of group shots, we'll make our peace with it.

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Some features require Windows 10. Updates available through Windows Store. Internet access required. Fees may apply. Microsoft, Windows and other registered trademarks or trademarks of Microsoft Corporation in the United States and/or other countries.

* Prices are including VAT and accessories at the time of printing, but subject to change.

PC Specialist recommends Windows



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Laziness gets a bad rap. We're constantly being told we should do more, work harder, maximise productivity. But there's another side to the story. Being lazy, it turns out, can be good for both our physical and our mental health. In fact, it may even be at the heart of what makes us human – and it's certainly a successful strategy for the sloth. Over the next 14 pages, we reveal why it might be time to live life in the slow lane.

ILLUSTRATION: LIME BROSSES

THE LAZY APE

Rather than language, tool use, or culture, is it our gift for laziness that makes us human?

WORDS: DR ANTONIO MARTINHO-TRUSWELL

Are we humans the laziest animals on Earth? It can be easy to think so. Endowed with the most powerful brains in the animal kingdom, we've put them to use making cars, computers, robot vacuum cleaners, coffee makers, automatic

money sorters, and audiobooks – every manner of device and system to minimise effort. Only the human has harnessed combustion that it might spare us the labour of walking. Only the human has erected supply chains so that fresh meat may be politely purchased from a nearby Waitrose

Dr Antonio Martinho-Truswell is a zoologist at the University of Oxford whose work is focused on learning and cognition.



rather than tracked and killed over a long hunt. We are masters of offloading work to machines.

If this is laziness, then laziness is a hallmark of our species. More than tools, language or culture, we are marked by the complex accessories that we build to do our work for us, both physical and mental. There are many tool-using animals, from chimps to cockatoos. A whole host of animals communicate using vocalisations that we could describe as language. A few animals build cultures by handing information down the generations. But only humans build systems to relieve them of those tasks. Artificial intelligence is simply the next stage in a long history of automation that's taken us from horses to steam to silicon and beyond.

LAZY BY NATURE

We humans can be quite judgmental about our lazy peers, but laziness is among the most valuable adaptations for successful life. And it's not just a human trait. In the animal kingdom, laziness is a necessity. Any animal – indeed, any organism – has to maintain a balance of energy in and energy out. If an animal profligately wastes energy by, say, moving around or working hard, and does not compensate for this with plenty of eating, then that animal will not survive for long. Laziness tells an animal how to manage this: if you do not absolutely need to do something, don't. This lazy impulse is just one of many impulses that propel an animal's life – so it does not always win out, and animals do frequently prance and play and preen – but the drive to conserve precious energy is always there.

Whenever we yoke an ox to a plough, or set an algorithm investing, we are, in a sense, achieving new heights in this common drive to laziness. More than just waiting to plough until we need to and then only ploughing what we need, we've arranged things so that we do not have to do the ploughing (at least not the hard part of it), but still get to do the eating. Our chimpanzee relatives are some of the smartest non-humans on the planet, but they don't come close to that kind of clever facilitation of doing nothing. In general, clever animals seem to be able to spend more of their time on laziness, and chimpanzees are no exception – they nap, socialise and play in a way that a mouse, constantly in desperate straits to stay alive, could only dream of. Despite this, though, chimpanzees still have hard work to do. Being large animals, they need to consume a lot of food and vitamins, and may spend almost 30 per cent of their time foraging – more than half their waking hours. They may be able to use stick-tools to catch nutritious termites to save some time, but we humans, with fast food and ready meals, spend almost none of our time sourcing food. Nor do many of us ●

“We can be quite judgmental about our lazy peers, but laziness is a valuable adaptation”



Automation means that a tiny percentage of the UK population is involved in farming, compared to previous times in history





ABOVE:
Automated
processes
make us more
efficient

RIGHT: Chimps
may have
mastered the
art of tool use,
but they still
need to spend a
lot of time
foraging for
food

● work in food production. Back in 1400, almost 60 per cent of the British workforce was involved in agriculture. Today, our laziness-enabling technology has that number down to around 1 per cent. Our ingenuity allows us to be lazier than the chimps.

But there's true laziness, and then there's efficiency. Every animal benefits from efficiency. Efficient strategies mean you can either get more energy in or reduce energy out in a shorter time or with less effort. In other words, efficiency is ultimately in service of laziness. The same drive to laziness that animates (or rather, dis-animates) all animals motivates our own labour-saving technology. A truly lazy ape would have embraced, at a species-wide



level, the opportunity for laziness that our technology allows. We, however, rebel against it – we always have.

Instead of satisfying ourselves with lives of supine relaxation, we are constantly looking for ways to be more efficient. With agriculture, we made keeping ourselves fed more efficient. We could have become lazy producing enough to eat in less time, and committing the spare hours to relaxation. Instead, we produce extra food, feed our livestock, and eat them instead. A lazy ape would have stopped with basic vegetable farming, but we put extra effort in because we like the taste of meat. We domesticated horses to allow some other beast to do some of our walking for us. A lazy ape would have stopped there, but we found we liked speed, and so have built every manner of vehicle to make transit faster and more comfortable. We built computers to handle our memory and calculations for us, but unsatisfied with that we are now trying to build artificial intelligence to make decisions without even asking us. A lazy move, to be sure, but a truly lazy ape would never have made it that far. Once they had enough to survive, they would've stopped.

So more than the lazy ape, instead I think we're the 'building ape'. We create laziness-enabling machines to free up more time and more resources to build something bigger. We scaffold technology upon technology and idea upon idea in pursuit of goals of which a lazy ape would never dream. Like every animal, we needed laziness to keep ourselves alive in times

of scarcity or to discourage any activity where costs might outweigh the benefits. But we have come out the other side of laziness. Most humans who read this won't have known real, threatening scarcity like the majority of animals face. We have the technology to be the laziest animal on Earth, and yet we are not lazy. We want to make things – more, better, bigger, different, and more complex. Even once all of our needs are met, we stand up, get back to work, and build. ●

DON'T WORRY, BE LAZY

It's tempting to kick back and relax over the warm summer days. Happily, there's scientific proof that this is exactly the right thing to do

WORDS: ANDY RIDGWAY ILLUSTRATIONS: ADAM GALE

SLOW DOWN AND IMPROVE YOUR HEALTH

Taking time out from the daily grind can benefit both body and mind

In a now-famous study carried out in 1999, psychologist Dr Robert Levine analysed the pace of life in cities in 31 countries, measuring things such as the speed at which people walk and the time it takes post office staff to hand out stamps. He found that the fastest pace of life was in Western Europe and Japan, and the fastest-living countries also had the highest rates of coronary heart disease. When British psychologist Prof Richard Wiseman repeated the experiment in 2006 by simply measuring walking speed, he found the pace of life had increased by 10 per cent.

The bigger the city, the faster our pace of life, and we're living faster than ever before. Dr Stephanie Brown, a psychologist who's written a book on the topic, describes our hunger for fast-paced living as an addiction. "People can't stop wanting to go faster," says Brown. "You begin to need more and more time on the computer. People talk about sleeping with their phones. You start to log on first thing in the morning. You cannot not do it. Your behaviours start looking like that first drink in

the morning. You need it." But there are signs of recognition of the problem. "Society is hitting a tipping point," says Brown. "I hope it's going to become embarrassing to have your phone out while you're eating dinner."

Brown suggests taking baby steps to overcome our addiction to living fast – perhaps first reducing the amount of time we spend checking email on our phones each day by five minutes, then introducing other steps. She says our gadgets are likely to have in-built limits as culture changes. Apple has already announced that iOS 12 lets users monitor how much time they're spending on their devices and apps.

As well as our overall pace of life, there's good reason to slow down a few other things, such as how quickly we eat. A study of nearly 60,000 Japanese people showed that those who ate slowly, or at 'normal speed' were less likely to become overweight than those who gobbled. It's thought that it takes 15 to 20 minutes for our body's feedback mechanisms to tell us we're full, so eating more slowly gives more of an opportunity for this to kick in. ●



ACHIEVE MORE BY WORKING LESS

Breaks and naps are no obstacle to a good day's work

The logic sounds simple: if you work more hours you'll get more done. But studies consistently show that our brains are a bit like muscles in that the more we use them, the more they get tired, so short, sharp stints of work with plenty of breaks is the way to go.

According to a study by software company Draugiem Group, the two magic numbers when it comes to the work-rest balance are 52 and 17—that's 52-minute working sprints with 17-minute breaks. It reached this conclusion by analysing data from productivity app DeskTime. Workers who achieved the most were the ones who tended to work in this pattern.

So what should you do during your well-earned breaks? Well, look at cute photos of kittens and puppies, of course. A study by researchers at Hiroshima University in Japan found that after students viewed images of kittens and puppies—as opposed to the adult versions of the animals—they were far more focused and performed better at a number-search game, as well as a game similar to *Operation* that required dexterity. This may be because the cute critters triggered the participants' inbuilt caregiving instinct, making them more attentive and vigilant.

As well as taking more breaks, even getting some daytime shut-eye can help. Researchers at the University of Pennsylvania found that people who napped for an hour at lunchtime performed better in recall tests and tests that involved solving maths problems than those who didn't nap, as naps give the brain a chance to recharge. Lengthy spells in the land of nod can even help keep the weight off. In a study of more than 1,500 middle-aged adults, Simona Bo at the University of Turin found that the adults who became obese in her six-year study period slept on average 6.3 hours a night compared with 7.2 hours for those who stayed at a healthy weight.





BOREDOM HAS ITS BENEFITS

A wandering mind is a creative mind

We tend to view boredom as an unwelcome guest – something to be rid of as soon as possible. But research is showing that there's good reason to embrace it.


"Boredom is a much maligned emotion, but it's very good for us," says Dr Sandi Mann, a psychology lecturer at the University of Central Lancashire. Mann's research involves making people downright bored. Her favoured technique is to encourage her volunteers to laboriously copy phone numbers out of a phone book, or even just read them in their heads. In one experiment, her bored volunteers were encouraged to think of as many ways as possible to use two plastic cups. It turned out that those who had become most bored – those just reading out the phone numbers – came up with the most ideas. In other words, they were the most creative.

"When you've got nothing to stimulate your mind, it creates its own stimulation," says Mann. "Your mind wanders and you daydream and that's really important as it allows you to make connections. You're free from the constraint of your brain saying: 'that's a ridiculous idea, it will never work'."

There's no doubting that boredom isn't always a force for good. There's growing evidence, for example, that the more boredom-prone are also more likely to become internet-addicted or experience 'problematic smartphone use'.

It seems that it's how we react to that feeling of boredom that's key. "Boredom is just a signal telling us to get up

and do something else," explains Prof James Danckert, a neuroscientist at the University of Waterloo in Canada. "Boredom is neither good nor bad, it's our responses that matter, turning towards self-destructive behaviours or becoming a spur towards creativity."

So harnessed correctly, boredom can become a force for good – inspiring creativity, and helping to unlock our hidden potential. 

Andy Ridgway is a science writer and lecturer.

"Your mind wanders and you daydream and that's really important"

THE POWER OF SLOTH

Why nature's laziest animal is an evolutionary success story

WORDS: LUCY COOKE

The sloth is a candidate for nature's most misunderstood animal. Saddled with a name that speaks of sin, the world's slowest-moving mammal has been eternally damned for its lethargic lifestyle. "These sloths are the lowest forms of existence," proclaimed the great French naturalist Georges-Louis Leclerc, Comte de Buffon. "One more defect would have made their lives impossible."

He couldn't have been more wrong. The sloth is a supreme survivor that has graced our planet for some 64 million years. A survey of a Panama rainforest in the 1970s found that an incredible one-third of the total mammalian biomass was made up of sloths. The secret to the sloth's success is its lackadaisical nature. They are energy-saving icons, performing about 10 per cent of the physiological work of a mammal of similar size, and boasting a suite of ingenious adaptations that allow them to exist on as few as 160 calories a day.

Lucy Cooke is a zoologist and author of *The Unexpected Truth About Animals* (£8.99, Black Swan) and *Life in The Sloth Lane* (£9.99, Workman).

1. CLAWS

Sloths are the world's only inverted quadrupeds, hanging from the trees of the tropical rainforests of South and Central America. Their toe bones are not separately movable, but bound together by ligaments, which along with their curved claws act as efficient hooks for dangling upside down. Their muscles have also evolved to suit their lifestyle. They manage almost exclusively with retractor muscles, like our biceps, which pull them along the undersides of branches.

2. STOMACH

Sloths subsist almost entirely on leaves. These are plentiful in the rainforest canopy, but are full of toxins and tough cellulose, making them hard to digest. To cope, sloths have evolved a four-chambered stomach, much like a cow's, and employ a host of gut bacteria to digest the leaves. It takes sloths up to a month to break down a single leaf; if it happened any faster, their liver might not cope, and they'd be in danger of poisoning themselves.

3. NECK

Sloths have up to 10 neck vertebrae: more than any other mammal. Even the giraffe makes do with just seven. In 2010, scientists at the University of Cambridge discovered that these appear to have evolved from ribcage vertebrae that were co-opted over time into neck bones. The long neck allows nature's couch potato to turn its head 270° and graze leaves all around it without wasting precious energy moving the rest of its body.




4. BODY TEMPERATURE

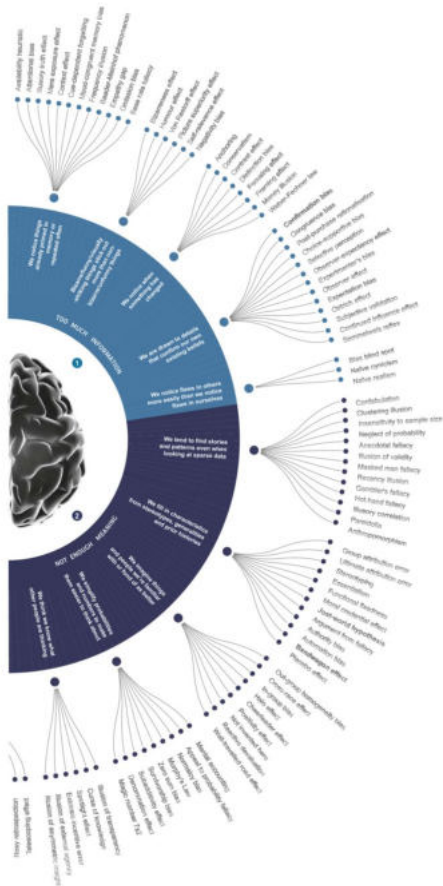
Sloths maintain a low core temperature of just 28°C to 32°C, whereas most mammals rely on a toasty 37°C. Rather than keeping themselves warm by stoking their internal combustion engine with calories, sloths wear a dense coat, worthy of an Arctic animal. Energy from the sunshine is free, and sloths bask like lizards to soak it up. Like cold-blooded animals, they're also able to withstand fluctuations in their body temperature of several degrees throughout the day.

5. CAMOUFLAGE

With an average cruising speed of just 0.3km/h, running from danger is not an option for the sloth. Instead, they avoid predation with their superb camouflage. Special grooves in the sloth's coat collect water and act as hydroponic gardens for as many as 80 different species of algae and fungi (as well as a wealth of insects), giving their fur a greenish hue. Each sloth is in fact a slow-moving miniature ecosystem that blends in perfectly with the trees.

6. STICKY RIBS

Sloths have evolved bands of tissue that anchor their guts to their lower ribs, preventing their massive stomach, which can make up as much as a third of their body weight in undigested leaves, from pressing down on their lungs. This adaptation makes breathing much less energy-intensive: researchers have estimated that the tissue fibres reduce a sloth's energy expenditure by up to 13 per cent, which is a significant amount when you have such a low-calorie diet. 



Human cognition is riddled with biases and shortcuts, most of which exist to give us a fighting chance of keeping up with events. Essentially, these biases have arisen to tackle four separate, but interrelated, problems that we experience on a daily basis (credit to Buster Benson here for doing the hard work and categorising all these biases)

① Sometimes there's just too much information in the world around us, so the brain prioritises new and interesting over familiar and mundane, even if the latter is contextually more important and we end up filtering out useful information. ② Sometimes we can handle all the information but we can't discern what it means, so the brain falls back on existing assumptions and stereotypes to cut through the uncertainty, even if these assumptions are invalid, or actively harmful.

4 Our brain has copious memory storage, but it can't remember everything. How does it know which memories are relevant or useful? Generally, memories are prioritised according to which are more stimulating or emotional. Unfortunately, real-world decisions often require logic and reason, so basing decisions on your most emotional experiences is often unhelpful.

And of course, impressive as they are, all these neurological processes take time, and the more complex and rational they are, the longer they take. Sadly, the world doesn't just pause and let us figure things out thoroughly, so our brains use 'instinct' and other emotional processes to make timely decisions. Unfortunately, these snap decisions can also be inaccurate and counterproductive.

It's good to know that all of these biases are happening, though – take some time to familiarise yourself with the 20 categories shown here. Once you're aware of these cognitive shortcuts, you can potentially adjust for them. Your immediate decisions may be riddled with problems, but your second or third? Turn over for more on eight of the brain's laziest shortcuts, which we've highlighted in bold in this infographic.

YOU SHOULD KNOW BETTER...

Eight lazy shortcuts your brain takes that are worth bearing in mind

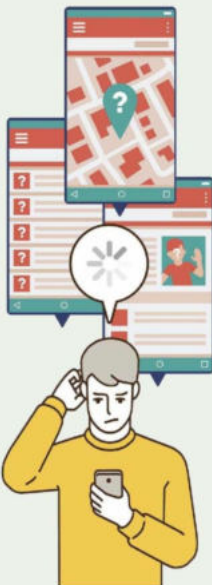
ILLUSTRATION: RAJA LOCKEY

1. BANDWAGON EFFECT

The tendency to follow the beliefs and ideas of others, regardless of your own beliefs.

2. FUNDAMENTAL ATTRIBUTION ERROR

The knee-jerk assumption that if something bad happens to someone else, it's because they're incompetent or at fault, whereas if the same thing happens to you it's because of bad luck.



3. GOOGLE EFFECT

The tendency to forget information that can be readily found online.

4. BIKE-SHEDDING EFFECT

The tendency for people to spend a disproportionate amount of time discussing trivial matters. For example, a committee debating the design of the staff bike shed in a new nuclear power plant.

5. CONFIRMATION BIAS

The tendency to latch on to and remember views that confirm our pre-existing beliefs.

6. RHYME AS REASON EFFECT

The tendency to perceive rhyming statements as more truthful.

7. JUST-WORLD HYPOTHESIS

The inherent assumption that the world is fair and that good actions are rewarded, rather than accepting it's largely random and then working harder to achieve positive outcomes.

8. PLANNING FALLACY

The tendency to assume a planned journey/task will go as well as possible, no matter how much prior experience there is to the contrary.



Dean Burnett is a neuroscientist and author of *The Happy Brain* (£12.99, Guardian Faber).

DISCOVER MORE



For the full list of cognitive bias definitions, head to bit.ly/cog_bias_1

LAZY WAYS TO SAVE THE PLANET

Sure, you could convert your house into a solar-panelled, rainwater-harvesting no-waste eco paradise. But doesn't that all require a bit too much... well... effort? Never fear, these tips can help you greenify your life without breaking a sweat

WORDS: LUIS VILLAZON ILLUSTRATIONS: ADAM GALE

1. Don't wash your clothes

Or at least, not so often. A single load of laundry generates 600g of CO₂, even if you wash at 30°C and dry it on the washing line. Tumble drying triples this. But the United Nations Environment Program and Levi's jeans both agree that you can wear trousers and skirts at least five times before washing them. The same goes for wool and synthetic sweaters, jackets and sweatshirts. If every household in the UK saved a whole laundry load per week, we would slash CO₂ emissions by 840,000 tonnes a year. For ordinary laundry, halving the amount of detergent will leave your clothes just as clean while reducing the phosphates that end up in our rivers. These cause algal blooms that kill fish and inhibit the natural biodegradation of organic substances.

2. Use a milkman

Supermarkets will only sell you milk in plastic jugs, or cartons made of laminated cardboard and plastic. But local milk delivery companies, such as milkandmore.co.uk, are starting to bring the glass milk bottle back to your doorstep. Glass now takes half as much energy to produce per tonne as it did 30 years ago. Recycling milk bottles is also much greener than other bottles because they can be washed and reused, rather than melting them back down to raw glass. Glass milk bottles, reused five times, generate 17 per cent less CO₂ per litre of milk than single-use plastic jugs. This rises to 60 per cent savings after 20 uses. You can even extend your breakfast laziness

3. Use a dishwasher

Washing up by hand can use less energy than running a dishwasher, but only with an efficient technique. If you rinse the plates and dishes under a hot tap and change the water in the bowl a few times, your handwashing session can generate 8kg of CO₂, compared with 1kg for a dishwasher cycle at 65°C. Using the dishwasher's 'eco' cycle will drop the washing temperature to 55°C and this reduces the carbon footprint by another 20 per cent. Loading and unloading the dishwasher also takes just a quarter of the time of doing the washing up. Remember, though, that dishwashers are only efficient when they are fully loaded. Soak dishes in cold water or run a cold rinse cycle, while you wait for enough dishes to run a full load. ●



4. Move in together

A 2015 study at Dickinson College, Pennsylvania in the US found that living with someone reduces your overall carbon footprint by 23 per cent, compared with living alone. Part of this is the obvious energy saving of heating just one house instead of two. Couples who live together also don't tend to go out in the evening as much, which cuts down on travel emissions. If you're worried about the effect on your relationship, the Marriage Foundation found that the ideal frequency for date nights was just once a month. If your retired parents move in, you'll cut down on even more unnecessary car mileage. Not only will you have weekday childcare right on the premises, but there will be no need for any long journeys at Christmas.

5. Don't mow your lawn so often

Although growing plants absorb CO_2 , a perfectly manicured lawn actually generates more greenhouse gases than it absorbs. An electric mower used for an hour, once a week through the growing season, results in an extra 15kg of CO_2 per year. Adding nitrogen-based lawn feeder makes things worse because some of the fertiliser breaks down to nitrous oxide which is 300 times more potent a greenhouse gas than CO_2 . Mowing once a fortnight is plenty, and if you leave the grass clippings on the ground, they will fertilise the soil just as effectively. Or kick back completely and swap your lawn for a wildflower meadow. By mowing just three times a year you'll boost plant biodiversity and encourage bees and butterflies.

6. Drive slower

Driving at 60mph (97km/h) instead of 70mph (113km/h) on the motorway uses 10 per cent less fuel but has negligible impact on your journey time. On empty roads, the journey from Bristol to London would theoretically take you an extra 16 minutes. But in normal traffic, we tend to accelerate until we catch up to the car in front, then brake to match speed until a gap in the overtaking lane appears, before accelerating away again. This driving style is much more stressful and uses more fuel because you are constantly accelerating and braking. Studies have found that typical journeys are just two minutes longer on average when driving at a steady 60mph and you'll save 0.8 litres of petrol for every 60 miles (100km) you drive. If every driver in the UK drove like this, it could save 810,000 tonnes of CO_2 per year. That's as much as a small gas-fired power station.

“Typical journeys are just two minutes longer on average when driving at a steady 60mph”



7. Work from home

The average commute time in the UK is 27 minutes each way. That's almost an hour every day that could have been spent in bed or with your family if you worked from home. Telecommuting isn't just easier, it's often more productive too. Studies have found homeworkers take just 1.8 sick days per year, compared with 31 for those in the office. Staying at home obviously reduces your total car miles, but companies with lots of telecommuters can also manage with smaller offices, which saves on heating and air conditioning costs. And your lunchtime salad or sandwich is less likely to come wrapped in lots of plastic. Overall, working from home just three days a week reduces your carbon footprint by the equivalent of four tonnes of CO₂ a year.



8. Bank online

The UK financial sector generates around 160g of CO₂ for every £1 we pay them in mortgage payments, loans, etc. Even though their business mostly consists of electronic data transfers, they still use energy to run the branches and offices. Banking online is more convenient and reduces the number of branches the bank needs to keep open. Security vans don't need to make as many trips to refill cashpoints if you use contactless payments with your card or phone. Plus, 10 per cent of the financial sector's carbon footprint goes on printing and postage, so opting out of paper statements will reduce emissions too.



9. Stop shaving

Worldwide, roughly 40 billion disposable razors are thrown away every year. They can't be recycled so they just end up in landfill, or worse, in the sea. The carbon footprint of wet shaving mostly comes from the hot water you use; switching to an electric shaver, which is less hassle, will use just 3 per cent of the electricity. That adds up to around 156,000 tonnes of CO₂ per year across the UK. If you abandon shaving altogether, you can also save the 0.95kg CO₂ from the shaver's manufacture. For women, the least environmentally-friendly option is to shave your legs in the shower. Every minute you spend shaving generates 240g CO₂ from the extra running water. Wait until you're having a relaxing bath anyway and then you won't use any additional hot water.

10. Skip holidays

One return flight to the Canary Islands adds the equivalent of almost a tonne of CO₂ to your carbon footprint. That's as much as you'll generate in six months of driving your car. Not only does air travel affect the climate more than all the world's cars, it is also the most exhausting part of going on holiday. If you travel to Europe by train you can be in Barcelona in nine hours. This is actually almost as fast as flying, once you factor in airport parking, check-in, security and baggage reclaim. Or give yourself the luxury of unlimited baggage allowance and take a cruise. You can sail across the Atlantic to New York in two weeks and turn the journey into the holiday. ☑

Luis Villazon is a freelance science and technology writer.

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SPACE

SPACE



WARS



FORGET THE TRADITIONAL BATTLEFIELDS OF LAND, SEA AND AIR. RAPID DEVELOPMENTS IN TECHNOLOGY AND OUR RELIANCE ON SATELLITES FOR EVERYTHING FROM COMMUNICATION TO NAVIGATION ARE PUSHING CONFLICTS INTO A NEW ARENA: OUTER SPACE

WORDS: Dr Stuart Clark



While addressing members of the US military at the White House recently, Donald Trump spoke of his desire to create a sixth branch of the United States

Armed Forces — one dedicated to conflicts in space. “I was saying it the other day, because we’re doing a tremendous amount of work in space — maybe we need a new force, we’ll call it the Space Force,” he said.

The comments may have drawn scepticism from some quarters, but many experts believe space war is indeed coming. According to the narrative, whatever conflicts start on Earth are going to quickly move into space. From there it’s easy to conjure up images of laser guns, exploding satellites and rockets arcing around Earth to take out orbiting targets. Better up there than down here, you may think. But dig deeper and the reality is very different and ultimately much more frightening. In fact, according to how you define space war, there’s an argument that says it’s already taking place.

“Unless you’re very narrowly defining space warfare as blowing up satellites and shooting lasers, there are elements of space warfare that date back to the Gulf War in 1991,”

says Prof Joan Johnson-Freese, at the US Naval War College, Rhode Island.

During that war, the GPS satellite navigation system allowed the American-led coalition to make a fast, accurate run across the Kuwaiti desert to outflank the invading Iraqi forces and ensure victory. Fast-forward to today and although the superpowers aren’t in open conflict with one another, they’re already testing each other’s space capabilities. In 2014, Chinese hackers broke into the US’s National Oceanic and Atmospheric Administration (NOAA) weather and satellite systems. Russian cyber warriors have also hacked satellite transmissions. And it’s a sure bet the US has done the same back.

The reason is that a superpower’s modern military relies on space as never before. Communication, navigation and surveillance are the foundations that allow a military force to achieve its objective.

Therefore the first thing combatants are going to do in any future conflict is try to remove these capabilities. But the space war cliché of actually blowing up the satellites will be a last resort for one simple reason: the amount of space debris it would create.

When a satellite fragments it generates tens of thousands of pieces of space debris. These circle the Earth at speeds of more than 7km per second. At these speeds, even a coin-sized piece of shrapnel will deliver the energy equivalent of an exploding hand grenade if it hits another satellite. This will instantly destroy it, creating tens of thousands more pieces of debris and making more satellite collisions inevitable. The kicker is that space debris is uncontrollable and so satellites



"EVERY SINGLE DAY WE RELY ON SATELLITES"

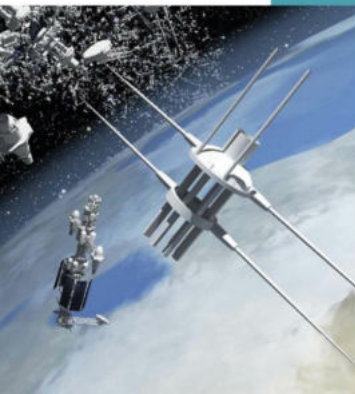
will be destroyed indiscriminately, meaning that yours will be taken down as well as those of your enemies. In the nightmare scenario known as the Kessler syndrome, we lose access to space entirely because there's so much junk up there that anything launched is instantly sandblasted into more debris. Losing space in this way would have major consequences not just for the military but for all of us.

Every single day we rely on satellites to make our lives easier. From weather reports to knowing when the bus is coming, talking to friends on mobile devices to watching videos online, everything uses data that's either generated by satellites or routed through them. If we lose the satellites, we lose our way of life. Hence the superpowers have been looking at other ways of disabling satellites but keeping them intact. And this is where the lasers come in. On 1 March, Russian President Vladimir Putin delivered his annual address to the Federal Assembly in Moscow. About

ABOVE LEFT Many of the world's militaries are putting more resources into cyber warfare – detecting it, defending it and waging it

BELOW One exploding satellite could cause a cascade of debris that makes it impossible for us to launch anything space ever again

GETTY IMAGES/PAUL HARRIS



KEY TARGETS

What will be in the weapons' sights?

COMMUNICATIONS SATELLITES

Blocking communications is an obvious first target during the outbreak of a conflict. But it's unlikely that the satellites themselves will be immediately destroyed. Instead, jamming them using laser systems on the Earth or disabling ground stations is the likely approach. "It's also the least escalatory because when you start blowing up other people's satellites that's going to get your enemy's attention very quickly," says Prof Joan Johnson-Freese, at the US Naval War College, Rhode Island.



GPS

Satellite navigation is inextricably woven into so much of everyday life that it's now a major dependency. The most well-known is the American Global Positioning System (GPS) but the Russians have the Global Navigation Satellite System (GLONASS), China has the BeiDou Navigation Satellite System (BDS) and Europe is bringing the Galileo constellation online. Each consists of multiple satellites, usually in medium Earth orbits of between 2,000km and 36,000km in altitude. Targeting the satellites of such a system would be seen as a major act of aggression.



EACH OTHER'S ANTI-SATELLITE SYSTEMS

In 2014, Russia launched a mysterious spacecraft that goes by the catalogue name 'Object 2014-28E'. It was launched along with three military communication satellites and originally it was thought to be a piece of space junk. Then it started manoeuvring. This sparked fears that it was an attack satellite capable of sidling up to other satellites and somehow killing them. In times of tension, any satellite that manoeuvres close to another would be seen as a major threat and targeted.



ATTACK TARGETS

LIVE ATTACKS

AGREEING ON TERMINOLOGY

Why it's so hard to ban space weapons

● 105 minutes into the presentation he said that Russia had begun equipping its military with laser weapon systems. He stated that he would not go into details but showed a video of an articulated truck with what looked like a large telescope attached to it. Such a system looks exactly like an anti-satellite laser weapon designed to dazzle spy satellites so they can't take images, according to Stuart Eves, a mission concepts engineer and industrial chair of the Space Information Exchange, the forum for the UK government to discuss emerging threats with industry. "There have been reports from the US that some of its surveillance satellites have been 'lased' from facilities on the ground," he says.

REPAIR OUR SATELLITES, DISABLE OUR ENEMIES'

So far, the satellites have only been blinded temporarily. But if the laser were trained on the satellite for long enough it could blind it permanently. And this is just the beginning. From space, other non-destructive military applications become feasible. Imagine a small satellite that flies close to an enemy's military communications satellite. It could sit alongside and listen to everything that's being transmitted. Or it could emit its own signal and jam the satellite's communications at a vital moment. And of course, there are those who are thinking of more direct approaches.

In the coming few years, we're going to see a slew of small satellites launched on servicing missions. These newly developed satellites will have the ability to rendezvous, inspect, even grab hold of other satellites and manoeuvre them. They're designed to extend the life of ageing communications satellites whose fuel is running low but whose payloads are still functioning. In effect, the small satellite will become a 'jetpack' saving the satellite's owners from the expense of having to replace it and lowering the cost of

ABOVE: The advent of space warfare may force a reassessment of conventional ground-based targets

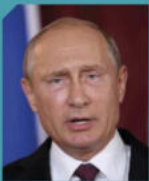
"If you launch a satellite that's manoeuvrable, technically that's a space weapon," says Prof Joan Johnson-Freesee, at the US Naval War College, Rhode Island. She points out that any satellite with a thruster can be used to ram another satellite, even though that's not what it was intended for. This 'dual use' has created problems for attempts to ban space weapons. In 1967, the Outer Space Treaty was ratified by most nations on Earth. It prohibited the placement of weapons of mass destruction in space. It said nothing about other types of weapons or anti-satellite systems however. So, in the 2000s there was an initiative sponsored by Russia and China to outlaw the stationing of any weapon in space. Sounds like a sensible idea but the US vetoed the treaty. "The US didn't buy into the idea of being able to sufficiently define a space weapon," says Stuart Eves, a mission concepts engineer who is also the industrial chair of the Space Information Exchange. Behind the scenes, the US was also developing space weapons that could be held in reserve and deployed if necessary. In a clear show of strength, in 2007 the Chinese launched a missile that blew one of their own satellites to smithereens. As for the Russians, they've had their own anti-satellite capabilities since the 1980s.

THREAT POSTURE

Who has the capability and the inclination?

RUSSIA

Alongside the US, Russia is the major player in space warfare. Since the earliest days of the space race, both sides have developed space weapons. In the early 1960s, Russia tested *Istrebiteľ Sputnik* (satellite fighter), which could approach a target and explode. Since then Russia has tested other systems that could be deployed if needed.



CHINA

It's clear that China feels threatened by the West's space capabilities. Its 2007 anti-satellite missile test was widely perceived as a warning that China can defend itself. China has also tested manoeuvrable satellites as part of its *Shijian* missions. These small craft are capable of intercepting and inspecting other satellites.



ROGUE STATES

Any attack on our space infrastructure from so-called rogue states such as Iran or North Korea is likely to come in the form of cyber-attacks. Although there's no way for them to win an all-out war against the West, they could target ground stations to disrupt our communications, simply to be a nuisance.



TERRORIST ORGANISATIONS

Terrorist organisations could also use cyber-attacks to target our space infrastructure and they probably have no qualms about escalations. They may feel that they're simply responding to acts of war perpetrated on them or wish to provoke a war. Either way they have little to lose, and lots of places to hide.



"NEARLY EVERYTHING IN SPACE IS A DUAL-USE TECHNOLOGY"

communications for us all. In more advanced versions, the service satellite will be able to reach in, cut into a fuel line and replenish the satellite's tanks. Sounds great, but spare a thought for the dark version of this scenario. What if the service satellite isn't owned by you? What if it approaches and pushes your satellite out of orbit or cuts a fuel line and leaves it bleeding into space? According to Doug Liddle, CEO of In-Space Missions Ltd, "Every mission that goes up to service a satellite could be used by an unscrupulous nation to damage it instead."

This grey area extends beyond servicing missions. In the same way that a knife can be used to eat a meal or to murder someone, "nearly everything in space is a dual-use technology," says Liddle.

So if we can't ban space weapons then the next best step is to restrict their use through international law. Warfare isn't necessarily a lawless free-for-all. Rules of engagement are internationally recognised guidelines about what can legally be undertaken by a military force. They're key to keeping military coalitions together.

An international consortium of law, military and space experts at the University of Adelaide Law School is putting together the *Woomera Manual*. According to the university's website, it "will become the definitive document on military and security law as it applies to space." The project will be completed by 2020 and then widely disseminated.

When it comes to space, these guidelines are needed more than ever because space is unlike any battleground that has ever previously been contested. Johnson-Freese believes that this changes the traditional rules of engagement. "In the army, in the infantry, you want to take the high ground because it gives you an advantage. Well, in space having the high ground with a satellite certainly gives you 24/7 coverage of areas you might not have been able to access but you're also a sitting duck because satellites travel in predictable orbits and they're the brightest objects against a dark sky, so they're relatively easy to target."

Apart from the space debris aspect, there's another pressing reason to avoid space war. It's a frightening reality that recent war gaming exercises have driven home. "Most of the results are highly classified," says Johnson-Freese, "but they do release some unclassified summaries. We know from the results they let out, space war escalates very quickly. And they can escalate from space to nuclear. So there's a definite interest in preventing that escalation."

But with the various superpowers continuing to probe each other's space capabilities, it's not an easy task. "Something like the Cold War is actually happening in orbit at the moment," says Eves. The job in hand is to stop it hotting up. ☐

Dr Stuart Clark is an astronomy writer with a PhD in astrophysics.

PUT THE MANTIS SHRIMP IN GOAL!

Six animals that could power up the World Cup

With the World Cup final fast approaching, we're looking to the animal kingdom for inspiration. If FIFA were to relax the humans-only rule, these are the critters we'd want to take the field

WORDS: HELEN GLENNY



CAPTAIN

CENTRAL MIDFIELD MEERKAT

Strengths: Teamwork, leadership
Weaknesses: May get distracted on the way out of the tunnel



WINGBACK DRAGONFLY

Strengths: 360° sight, excellent movement
Weaknesses: Gets distracted easily



GOALKEEPER MANTIS SHRIMP

Strengths: Punches so fast that everything it touches explodes
Weaknesses: Punches so fast that everything it touches explodes



CENTREBACK HONEY BADGER

Strengths: Aggression, injury-resistance
Weaknesses: Doesn't play by the rules



WINGER PRONG-HORNED ANTELOPE

Strengths: Maintains high speeds over 90 minutes
Weaknesses: Likely to refer to the sport as 'soccer'



STRIKER KANGAROO

Strengths: Most powerful kick
Weaknesses: Throws punches when it's riled up

1 Harry Kane had better watch out – female meerkats are the animal kingdom's ultimate team leaders. Matriarchal mobs form around an alpha female who directs the pack when it's threatened. As excellent sentinels, they always have a watchful eye on what's going on in the game, communicating through barks when opposition is on the attack. Meerkats live in large societies, so they've got teamwork nailed.

4 Even the niftiest attackers will struggle to outwit the dragonfly. It has up to 30,000 facets on each eye, which give it 360° sight, while four wings mean it can move forwards, backwards, sideways, up and down without changing orientation. What's more, dragonflies don't react to prey moving; they predict their prey's movements before they even occur. Good luck dribbling round one of these creatures.

2 To get the ball out of the box at speed, you need a mantis shrimp. The peacock mantis shrimp seen here might only be 10cm long, but with its specialised 'clubs' it can punch through water with enough force to cause an explosion. Let's see Jordan Pickford do that. But there might be a few issues; some species use their sharp forelimbs to stab prey, and we're not sure what rules FIFA has for punctured balls.

5 Footballers need to be nippy on their feet, but also have to possess enough endurance to last the full 90 minutes of a game. Neymar's got some legs on him, but even he'd look a little sluggish up against a prong-horned antelope. These four-legged beasts can maintain a speed faster than Usain Bolt for about an hour, and will keep on going at a fair old pace after that – useful if the game goes to extra time.

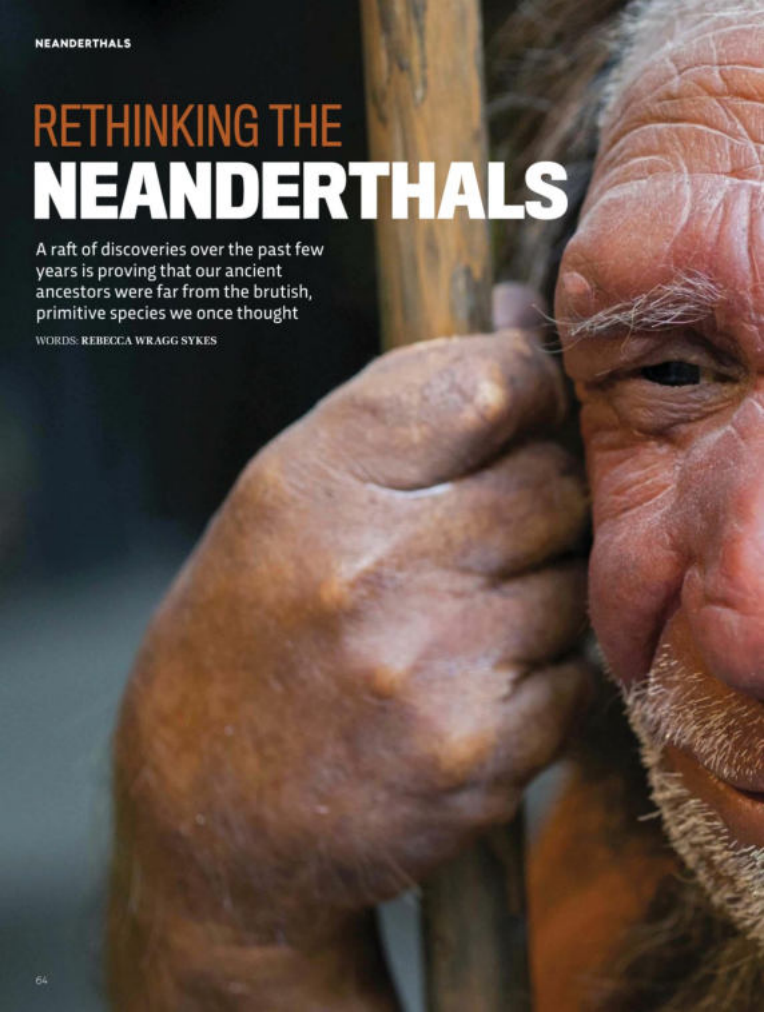
3 For aggression, recruit the honey badger. You're guaranteed a no-mercy defender that won't be lost to injury. Its skin can withstand multiple blows from a machete – long enough for the ref to blow the whistle and cart that machete-wielding maniac off the pitch. The honey badger has some wrestling moves that Sergio Ramos would be proud of. He's a prime candidate for red cards, but he'll do some damage first.

6 When it comes to pure firepower, the red kangaroo can't put a foot wrong. Australians aren't usually known for their football prowess, but this native can balance on its tail and use both feet to kick with net-ripping force. Ronaldo's kick can shatter glass from 20m out, but one swift boot from a red kangaroo can break bones. They punch hard too, so let's make sure any kangaroos we field can keep their tempers under control.

RETHINKING THE NEANDERTHALS

A raft of discoveries over the past few years is proving that our ancient ancestors were far from the brutish, primitive species we once thought

WORDS: REBECCA WRAGG SYKES



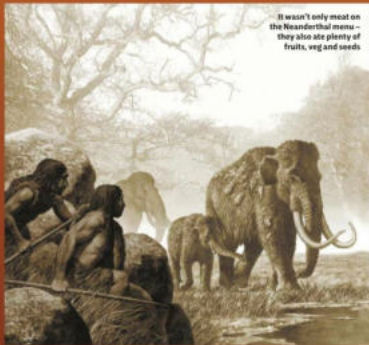


Until Neanderthals' disappearance some 40,000 years ago, they were our closest relatives. But ever since we discovered this hominin species in 1856, we've tended to stereotype them as brutal, unsophisticated 'cavemen'. This is a view that's now looking increasingly outdated. As scientists reveal new insights into Neanderthals' lives – from their use of plants, to their family life and their artistic skills – the notion that they were an inferior species is being debunked once and for all.

THEY WERE GOURMETS

Neanderthals lived across Eurasia, from North Wales to Palestine, and all the way into Siberia. With such a colossal range, it's no wonder that they ate a variety of foods. They hunted cooperatively in groups to capture formidable creatures such as bears, rhinos, and giant camels (now extinct). They fashioned wooden spears for close-quarters jabbing, while others they threw like lances. After the kill, they deployed expert skills to skin and butcher their prey, removing the fattiest meat from haunch to brain, even smashing and possibly boiling bones for their nutritious marrow.

As well as big game, Neanderthals caught rabbits and birds, and collected shellfish. Fruits and nuts, including pistachios, walnuts, pine nuts, date palm, figs, olives and grapes, also played a surprisingly large role in their diet. Meticulous examinations of distinctive wear patterns and microscopic residues on their teeth published in 2016 have confirmed that foods which needing peeling or hulling like tubers (wild radish, water lily) and seeds (wild cereal, peas, lentils) were on the menu right across Europe. We've even found evidence at sites as far apart as Belgium and Iraq that they cooked plants, from dry-roasting to boiling. It seems that no matter when or where they lived, Neanderthals took full advantage of nature's bounty.



It wasn't only meat on the Neanderthal menu – they also ate plenty of fruits, veg and seeds

THEY WERE ARTISTS

There's evidence that Neanderthals were creative, with an understanding of symbolism. In the past decade, a flurry of sites have revealed that they collected bird feathers and talons. Meanwhile, meticulously carved stones and bones have been found that have no obvious practical explanation. About 50,000 years ago, Neanderthals engraved the stone floor of a cave in Gibraltar to create a 'hashtag' design (a strange echo of 21st-Century life).

We've also been finding pigments. Practical uses for the pigments are possible, such as ingredients in glues for tool-making, but some examples are hard to argue as utilitarian. These include a fossil shell in Italy smeared with red ochre at least 45,000 years ago, and shells discovered in Spain with yellow and red pigments mixed with the sparkly mineral pyrite. Just this year, paintings in three Spanish caves were dated to more than 10,000 years before *Homo sapiens* are known to have been in this part of the world. The discoveries include painted stalagmites, a vertical red line and the shape of a hand outlined by red paint. If the dating is correct, then this could mean that when humans entered Europe, they found caves already filled with Neanderthal art.



Cave art in La Vache, Spain, was daubed on the walls by Neanderthals some 64,000 years ago



Evidence suggests that Neanderthals could have intentionally buried their dead

THEY HAD FAMILIES

Neanderthals seem to have lived in small, family-orientated groups, with daily lives built on close emotional bonds. Birth was probably risky, and infants would have needed nursing and carrying for more than a year. Children joined in adult activity early: heavy work marked their bones, and tiny scratches on their teeth show that they learnt to eat with stone knives. At the end of life, we know that Neanderthal death traditions were complex. Scrutiny of bones from across Europe has identified cut marks showing that the bodies of the deceased were often carefully taken apart, and sometimes even eaten – a way of coping with death that's more common in history than you might think.

But Neanderthal relationships weren't limited to their own species. In 2010, it was revealed that modern humans (*Homo sapiens*) interbred with them, and genes moved in both directions. In 2015, genetic analysis of a 40,000-year-old human jawbone from Romania found Neanderthal ancestry within only six generations. Finding such a close relationship by chance in some of the oldest European human remains is unlikely, so interbreeding was probably common at this time. The amount and diversity of Neanderthal genes in our DNA points to hundreds – if not thousands – of human-Neanderthal encounters. We don't know who raised the resulting offspring, or if groups lived and socialised together, but these babies would have required the same devoted care and love as our own.



The Levallois technique allowed Neanderthals to create a wide range of stone tools

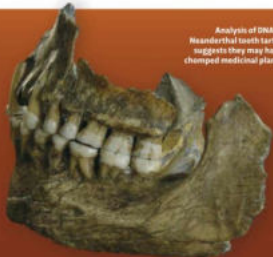
THEY WERE CREATIVE

One of the most persistent myths about Neanderthals is that their technology was static and simple. In fact, we see clear changes over the hundreds of thousands of years they existed, from the way they knapped (shaped pieces of stone to make tools and weapons) to the specific products they made. Neanderthals were innovators, too: they developed the 'Levallois technique' of knapping, which allowed greater control in the size and shape of the pieces they removed from stone blocks, and invented the first synthetic material, 'birch tar'. This was distilled from the bark of birch trees with carefully controlled fires, and used as a glue for tool handles.

Neanderthals also worked with materials other than stone. They selected bones for their knapping kits, and sometimes shaped them for smoothing tasks, which probably included working animal hides into furs and skins. Just like many traditional societies today, Neanderthals also used their mouths as a 'third hand' when cutting things, which left tiny scratches on their teeth. Some Neanderthal women have been found to have scratches that were shaped differently to those of the men, suggesting that they had their own specific tasks.



Analysis of DNA in Neanderthal tooth tartar suggests they may have chewed medicinal plants



THEY WERE MEDICS

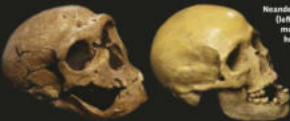
We can reconstruct a jaw-dropping amount of information about Neanderthals from their teeth: tiny grooves reveal where enamel growth was affected by severe illness or malnutrition. A 2017 study analysing the dental tartar of Neanderthals from El Sidrón, Spain, found DNA from multiple bacteria, including those causing gum disease, diarrhoea, and whooping cough. Intriguingly, one adult with a tooth abscess was also found to have DNA from a *Penicillium* mould (a natural source of penicillin) in his tartar. This may have been eaten by chance, but it's just possible that this Neanderthal was self-medicating.

Elsewhere, there are at least two cases of injured arms being amputated, while a number of individuals have been discovered with severe injuries that probably meant they were temporarily unable to walk, requiring medical care. We also know that Neanderthals collected and chewed bitter plants like chamomile and yarrow. Neanderthal DNA tells us that they had taste receptors for the acrid compounds in these plants, so it's possible that they consumed them for medicinal rather than culinary purposes.

WHY DID THEY DISAPPEAR?

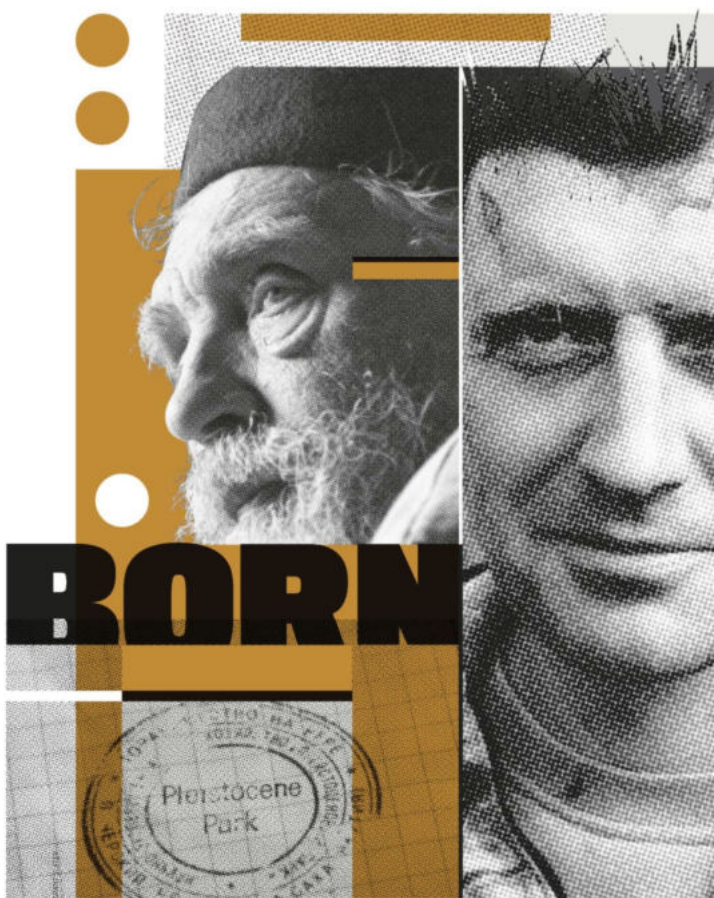
Neanderthals never really went extinct, at least not genetically. Between 20 and 70 per cent of their genome lives on in us, spread among various human populations in Eurasia. In terms of quantity of DNA, there are actually more 'Neanderthals' around now than ever. Yet between 40,000 and 35,000 years ago, their fossils disappeared from the record, so the question is: why did we absorb them into our species, and not the other way around?

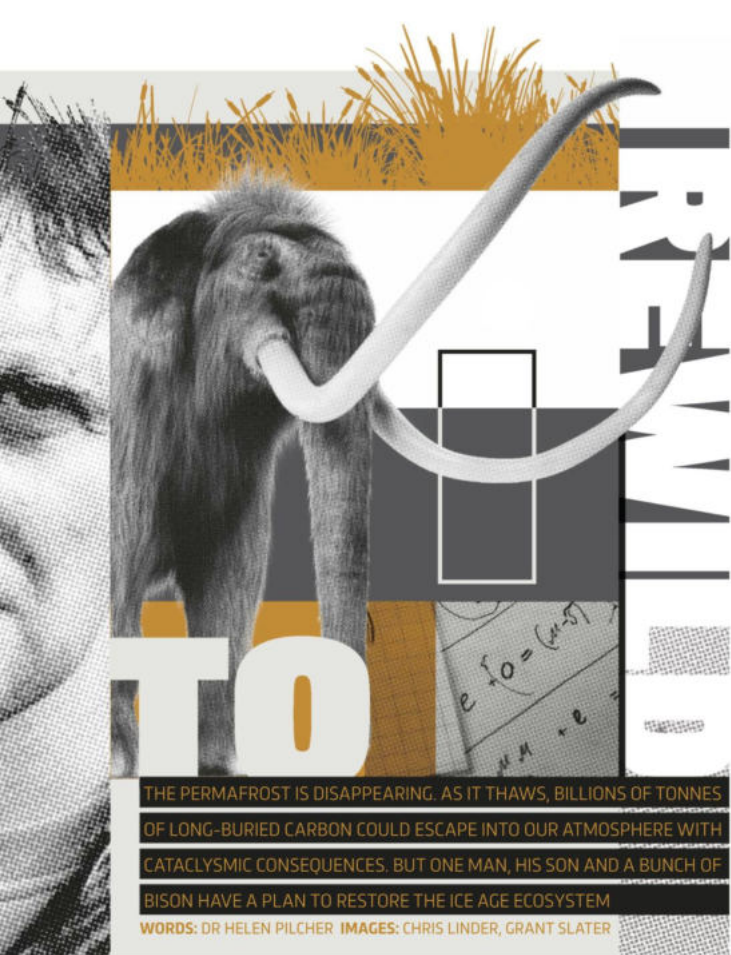
Proposed theories for our potential superiority have included a broader diet, more efficient tool manufacturing, and even a mastery of symbols and art. But these all look less certain in light of the evidence described in this article, and it's likely that a number of effects played a role. While Neanderthals had lived through many periods of extreme climate change, the conditions around 55,000 years ago became extraordinarily unstable. If *Homo sapiens* had even marginal advantages in coping with this instability – perhaps more effective weaponry (allowing us to obtain more food), or extended social networks – then over time this would have built up. On millennial scales, a few extra human babies surviving per year could eventually snowball into a total population replacement, especially if Neanderthals' genes were being diluted by breeding with us. Their fate wasn't a dramatic annihilation, but a slow, irreversible assimilation. **Q**



Neanderthal (left) and modern human

Rebecca Wragg Sykes is an archaeological researcher, specialising in Neanderthals. Her book, *Kindred: Neanderthal Life, Love, Death And Art*, is out next year.





THE PERMAFROST IS DISAPPEARING. AS IT THAWS, BILLIONS OF TONNES OF LONG-BURIED CARBON COULD ESCAPE INTO OUR ATMOSPHERE WITH CATAclySMIC CONSEQUENCES. BUT ONE MAN, HIS SON AND A BUNCH OF BISON HAVE A PLAN TO RESTORE THE ICE AGE ECOSYSTEM

WORDS: DR HELEN PILCHER **IMAGES:** CHRIS LINDER, GRANT SLATER

It sounds like the plot from a Hollywood blockbuster. Eight time zones east of Moscow, in a remote corner of Siberia accessible only by boat, two men are trying to save the world from calamitous global warming. One, Sergey Zimov, is

a pony-tailed man with a ZZ Top beard and penchant for concocting grand theories and smoking roll-ups; the other is his long-suffering son, Nikita. Their plan is to create an Ice Age nature reserve full of Ice Age creatures that will act as climate change superheroes. Their only superpower is digestion. In a nod to the Stephen Spielberg classic, the Zimovs have decided to call their venture Pleistocene Park. Meanwhile, 9,000km away in a Harvard University laboratory, a bunch of scientists are working to bring back what could become the park's star attraction – the ultimate Ice Age icon, the woolly mammoth. But time is running out and the odds are stacked against them. Can the intrepid scientists succeed before the frozen north melts?

ON THIN ICE

Scientists estimate that 1,400 billion tonnes of organic carbon lies locked up in the permafrost, the frozen sub-surface layer of soil, ice and rock that covers around one-quarter of northern hemisphere land. That's roughly twice as much carbon as exists in our atmosphere, and three times the amount found in all the world's forests combined. Now, as our planet warms and the permafrost melts, microbes are starting to convert this organic carbon into methane and carbon dioxide. The concern is that as these greenhouse gases bleed into the atmosphere, they will accelerate the rate of global warming, leading to more melting and microbial activity. "We are rapidly approaching the point where the Arctic permafrost will start thawing everywhere," says Nikita, who now manages Pleistocene Park. "That will be catastrophic but we hope that Pleistocene Park will make a difference." ●

"WE ARE RAPIDLY APPROACHING THE POINT WHERE THE ARCTIC PERMAFROST WILL START THAWING. THAT WILL BE CATASTROPHIC"



ABOVE: Ancient bones collected from an eroding riverbank by Sergey and Nikita Zimov and students over the course of just one day

BELOW: This river, with its many side-channels, oxbows and meanders, is very representative of northern Siberia



Sergey
and Iekim
Zimov plan to use
grazing animals to
keep the
permafrost
frozen

123

750



● The Pleistocene is the moniker given to the last Ice Age, an interminable cold spell that began around 2.5 million years ago. It was a time when immense ice sheets waxed and waned over much of the northern hemisphere, locking up so much water they created cloudless blue skies. Beneath those skies were lush, open grasslands that covered much of Eurasia and North America; the so-called mammoth steppes. When *Homo sapiens* first set eyes on this vista, tens of thousands of years ago, it was a vibrant and biodiverse place. Immense herds of mammoth, bison, reindeer and horses roamed the plains, amidst watchful cave lions and wolves. "It was like an Arctic Serengeti," says Nikita. "Modern humans didn't need to worry about finding food; they needed to worry about being trampled."

When the Pleistocene came to an end around 11,500 years ago, it all disappeared. Many of the biggest animals, including mammoths, woolly rhinos and cave lions went the way of the dodo, and the grasslands were replaced with an unkempt ragbag of scruffy tundra and scrawny saplings. Now the remains of that Ice Age ecosystem lie trapped in the permafrost.

Thirty years ago, most scientists thought this transition was driven by climate change. As the Ice Age drew to a close, warming caused the pastures and animals to die. Then Sergey put forward a new theory, which he outlined in a Soviet journal in 1988.

PARK LIFE

It's well known that animals provide ecological services to the environment in which they live. According to

ABOVE: The Siberian environment near Pleistocene Park

RIGHT: The Zimovs have a herd of Yakutian horses at Pleistocene Park. The animals are native to Siberia and grow long coats in the winter

BELOW RIGHT: Beneath the 'active layer' of soil (only a metre or so deep), the ground is ice-filled soil called permafrost. This cave, which was hand-carved from the permafrost by the Zimovs and their workers, is located in Pleistocene Park and is as an rat freezer refish



IMAGES COURTESY OF PLEISTOCENE PARK

Sergey, during the Pleistocene, big herbivores would have kept weeds and forests at bay, and returned nutrients to the ground via their droppings. In summer, they helped send the Sun's warming radiation away from the planet by maintaining grassland, which is more reflective than closed woodland. In winter, the herbivores broke up the snow and helped keep the ground frozen by exposing it to the bitter Arctic air. If the big grazers could be returned, he mused, they should be able to convert the mossy tundra back to productive grassland and help keep the permafrost frozen.

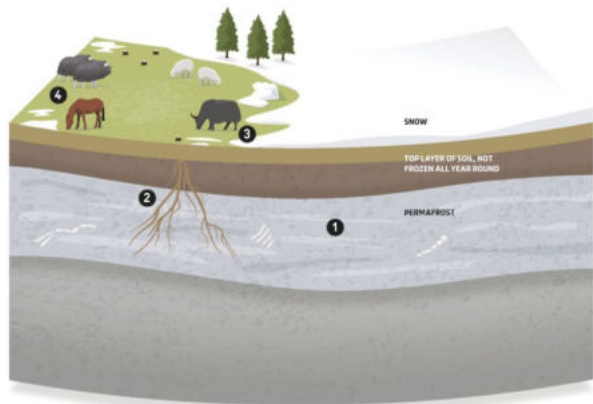
In 1996, he set up Pleistocene Park to test his ideas. The reserve, which lies close to the Kolyma River in the Sakha Republic, northeastern Siberia, incorporates 2,000 hectares of this barren tundra. With no funding, in the early days the project ran on fumes and enthusiasm. First, he acquired some stocky, semi-domesticated horses from Siberian natives who used them for meat. He fed the horses with porridge oats, but without any fences, the ungrateful animals just wandered off.

Fast-forward to the present day, and the father and son team have added more than 25km of fences, 30 sheep, 30 reindeer, 9 yak, a few musk ox, some bison

"IT WAS LIKE AN ARCTIC SERENGETI. MODERN HUMANS DIDN'T NEED TO WORRY ABOUT FOOD; THEY NEEDED TO WORRY ABOUT BEING TRAMPLED"

and a couple of dozen horses, all species that lived in Siberia during Pleistocene times. Shrubs that were once so tall they overshadowed people have now been grazed to waist height or less. Tussock, a common, slow-growing weed, is giving way to meadow grass. Slowly but surely, the mammoth steppe ecosystem is beginning to return. "It's the start of a long process," says Nikita, "but there are encouraging signs."

The ability of animals to re-sculpt landscapes is well known. There are many examples where keystone



1 Permafrost is made of frozen soil, rock, water and organic matter, including animal bones and plant roots from the Ice Age.

2 As the permafrost melts, the roots of grasses that grew in the Ice Age are being devoured by hungry microbes. If oxygen is

present, carbon-based sugars locked inside the roots are broken down to form carbon dioxide, but if the soil lacks oxygen then methane is made. Both methane and carbon dioxide are greenhouse gases with the potential to accelerate global warming.

How grasslands and grazers can help keep the permafrost frozen...

3 In the winter, grazers trample through the snow exposing the earth to bitterly cold Arctic air. This helps keep the ground frozen and carbon locked away.

4 In the summer, grazers promote the formation of lush, biodiverse grasslands by eating weeds, dispersing seeds and fertilising the ground. They help keep forests at bay by knocking down trees and eating their bark. These grasslands reflect more sunlight than forest and scrub, causing the Arctic to absorb less heat.

ECOSYSTEM ENGINEERS

It's not just Siberia that can reap benefits from introduced animals



THE GRAZERS OF OOSTVAARDERSPLASSEN

In 1968, a polder (a tract of lowland reclaimed from the sea and protected by dikes) in the Netherlands was drained to create a marshy nature reserve. Konik ponies, Heck cattle and red deer were

introduced to mimic the grazing of extinct herbivores. They created enormous grasslands that provided habitat for geese and birds, but the reserve attracted controversy in 2016 when half its grazers had to be shot when they became malnourished after a harsh winter. There was not enough food to go around, prompting ecologists to highlight the need for predators to regulate herbivore numbers.



REWILDING AT THE KNEPP ESTATE

In 2002, the cows on a failing West Sussex dairy farm were replaced by free-roaming Longhorn cattle, Exmoor ponies, fallow and red deer, and Tamworth pigs. Since then, nature has

taken over. The animals have created new habitat and the rewilding success story now boasts nightingales, turtle doves and peregrine falcons, not to mention Britain's largest population of purple emperor butterflies.

THE WOLVES OF YELLOWSTONE

When wolves were reintroduced to Yellowstone National Park in 1995, after a 70-year absence, things changed radically. The elk they preyed on learned to avoid the steep-sided valleys where they could be trapped by the wolves, so these areas regenerated. Woody plants and trees shot up. Their roots stabilised riverbanks, so waterways became more fixed in their course. Songbirds came. Beavers returned, built dams and created ponds that provided habitat for fish, amphibians and reptiles. The wolves killed coyotes, leading to an increase in small mammals, which attracted weasels, foxes and birds of prey. From an ecological perspective, the wolves were a howling success.



ABOVE: Pleistocene Park is the brainchild of Sergey Zimov

RIGHT: The house is one of the buildings at the Northstar Science Station, where Sergey, Nikita and their families live and work





• species, also known as ‘ecosystem engineers’ have influenced local flora and fauna, not to mention geology. So the Zimovs chose their animals based on the ecological roles they perform. Sheep, for example, are good at eating weeds, horses mow the grass, while reindeer are partial to mosses and lichen. During the Pleistocene, mammoths were a keystone species. But the Zimovs haven’t had access to these hairy pachyderms... until now.

MAKE A MAMMOTH

Last year, Harvard University geneticist Dr George Church announced he was a few years off making a mammoth-like embryo. Church and his team are using CRISPR-Cas9, the system that enables scientists to edit DNA with pinpoint precision, to manoeuvre mammoth genes into elephant cells. Mammoth DNA, prised from Ice Age remains, has been decoded. By comparing the genomes of 23 individuals, Church has been able to pinpoint particular mammoth genes that were favoured by natural selection. “We have chosen 44 genetic changes based on this analysis,” says Church. These include genes that code for mammoths’ insulating fat and fur, as well as a unique version of the haemoglobin molecule that works well at low temperatures.

Once the edits are completed and checked, the cells will be used to create embryos. In an ideal world, these would be nurtured inside elephant surrogates, but with the world’s pachyderms so desperately endangered, their wombs are strictly off-limits. Instead, Church is pioneering the use of artificial wombs and last year made significant progress towards this goal when he nurtured a mouse embryo inside an artificial womb for 10 days; halfway through its normal gestation period. If Church succeeds, the result will not be a pure woolly mammoth, but a hybrid that is essentially a cold-adapted elephant. You could even call it a mammophant.

Later this year, the Zimovs expect Church to visit Pleistocene Park where he will see their newly created

ABOVE: Lyuba, who was found in Siberian permafrost, is the best-preserved mammoth mummy in the world. Scientists can extract DNA from such specimens to help decipher their genetic code and potentially create elephant-mammoth hybrids

ABOVE RIGHT: Geneticist Dr George Church is just a few years away from making a mammoth-like elephant

“THE RESULT WILL NOT BE A PURE WOOLLY MAMMOTH, BUT A HYBRID THAT IS A COLD-ADAPTED ELEPHANT”

grasslands. When Church’s mammoth-like elephants are ready, the nature reserve could become the first of many places where the shaggy beasts roam. Sergey now spends most of his time at a second park they have created, Wildfield, 250km south of Moscow, and ultimately the duo envisage a network of similar reserves spanning Siberia and Alaska. “We need to take huge territories. This is a century-long plan,” says Nikita. Immense numbers of animals will need to be imported, including predators to keep the grazers in check. “We have bears, wolverines and polar foxes but we need wolves and maybe Siberian tigers,” says Nikita.

Crucially, experiments performed at Pleistocene Park have shown that where big herbivores graze, soil temperatures are, on average, several degrees cooler than where grazers are absent, which is tantalising evidence that the Zimovs’ approach could help keep the permafrost frozen. “Sergey Zimov is a remarkable character,” says permafrost scientist Max Holmes from the Woods Hole Research Center, Massachusetts. “He has big, crazy ideas and a lot of them turn out to be right.”

In the meantime, the permafrost is slowly, patchily starting to thaw, and in Siberia the consequences are



**“LIKE WOOLLY MAMMOTHS,
BISON ARE A KEYSTONE
SPECIES. THEY CAN FASHION
ENTIRE ECOSYSTEMS”**

❶ all too apparent. Enormous sinkholes are appearing and huge chunks of land are falling away. Most buildings in the region rest on permafrost, but with their foundations slowly melting, entire houses are sinking into the mud. Nikita thinks that Pleistocene Park's nearest town, Cherskii, will collapse in the next 30 years, displacing all of its 2,500 residents.

“We’re not losing a lot of carbon from the permafrost right now,” says Holmes, “but we are headed in that direction.” If we continue to burn fossil fuels at the





rate we do now, we stand to lose around 1.5 billion tonnes of carbon per year for the rest of the century. "That's like adding another USA into the mix," explains Holmes. Pleistocene Park, and its extended network of Ice Age nature reserves, could help slow the loss. "I think Pleistocene Park could make a difference," says Holmes. "I don't think it's the solution to climate change, but I think it could be a small part of the solution."

The Zimovs, however, aren't putting things on hold to wait for the tens of thousands of mammoths that would be needed to help manage the region's forests. They believe they can recreate the mammoth steppe ecosystem without the woolly beasts.

In the past, both Sergey and Nikita have been known to mimic the actions of mammoths by driving around in a battered Ukrainian tank they bought over a decade

ABOVE: Vehicles were once used to bulldoze trees in Pleistocene Park to encourage the growth of grasses. Now, herbivores are used instead

ABOVE LEFT: Enormous herds of bison once roamed Siberia, so the Zimovs have introduced them to Pleistocene Park

BELOW: It's a race against time to stop the permafrost from melting

ago. It took them two months to drive it from the Russian border to the park. "We used it to knock down trees when we were building fences, and when we were entertaining journalists," says Nikita. "But it's broken now and we don't want to change the ecosystem with a tank. It's not efficient or sustainable. We want the animals to do it for themselves."

So now they are turning to bison, rather than tanks. Like woolly mammoths, bison are a keystone species. They can fashion entire ecosystems by trampling, grazing and fertilising. And they kill trees, not by knocking them down, but by eating their bark. Until recently, Pleistocene Park had only one bison, a male that came from Europe, but according to Nikita, this sole animal was responsible for most of the major changes seen in the park. These encouraging findings made bison a number one priority for the Zimovs, and at the start of June a dozen baby bison from Alaska were put into crates and loaded onto a 74-year-old DC-4 aeroplane. Destination: Pleistocene Park. The hope now is that when they settle into their new home, these natural geoengineers will set to work doing what they do best – being bison – and turn their environment into a grassier, greener and colder place. So although the media love nothing more than a shaggy mammoth story, when it comes to sculpting ancient grasslands, it's bison that are likely to be best. **Q**

Dr Helen Pilcher is a science writer and speaker. Her latest book is *Bring Back The King: The New Science Of De-extinction* (£16.99, Bloomsbury).

DISCOVER MORE

1 Visit the Science Focus website to read all about the 'tuskers' who are blasting through the Siberian permafrost in the hunt for mammoth ivory bit.ly/MammothHunting





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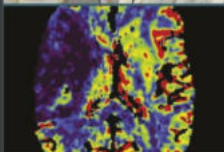
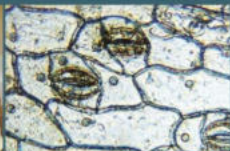
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PROF ROBERT MATTHEWS
Physicist,
science writer

YOUR QUESTIONS ANSWERED

SUMMER 2018

EDITED BY JAMES LLOYD

Why (and how) does dew form?

ERIN BEACH, HIGHLANDS

During the day, water evaporates from rivers and lakes, and plants pull it up through their roots and release it from their leaves. In the evening, the air cools

and can't hold as much water vapour. The excess condenses into water droplets, which collects on any cold surfaces near the ground, where there is less wind. **EW**



Do any other animals play music?

ALEX HACKETT, SOGNOR REGIS

Plenty of non-human animals create sounds that we might consider music, and there's even a whole field of study dedicated to this idea: zoomusicology. Birdsong is undoubtedly the most familiar of these sounds, but is it truly music? A 2012 study of nightingale-wrens found that their songs don't match up with Western musical scales, so the musicality of birds might be something of an illusion – to our ears, at least. For the most human-like music, we might need to go underwater. The male humpback whale produces complex songs with structures that are remarkably similar to our own, consisting of looping sequences of 'melodies' and repeating 'end phrases' akin to the rhymes in song lyrics. Little wonder that 1970 album *Songs Of The Humpback Whale* went multi-platinum. **cc**

What do the other planets smell like?

DUNCAN SIMMONS, PLYMOUTH



Astronomers recently found that the atmosphere of Uranus has high levels of hydrogen sulphide, a compound that smells like rotten eggs. The only first-hand account of the smell of another celestial body came from the Apollo astronauts, who claimed that Moon dust smelt like spent gunpowder. Mercury has a very sparse atmosphere and so would not have much of a smell at all. Venus and Mars, much like Uranus, have substantial quantities of eggy hydrogen sulphide. For Jupiter, the smell would depend on where you were in the atmosphere. Some regions have high concentrations of ammonia (which smells like cleaning fluid), others hydrogen sulphide (eggs) and others hydrogen cyanide (bitter almonds). Saturn and Neptune probably don't have much of a smell because they're composed chiefly of the odourless gases hydrogen and helium. **AG**



Why does laundry smell better if it's been hung up outside?

WILLIAM PEDEN, NORWICH

Unless you wash clothes on a 90°C cycle, they will still have bacteria trapped in their fibres. The warm, damp conditions after the clothes come out of the machine will encourage growth of the bacteria, and the waste compounds they excrete will create a stale, funky smell. Hung outside, clothes generally dry much quicker, and the ultraviolet light from the Sun kills bacteria quite effectively. In spring and summer, clothes might also trap pleasant-smelling volatile organic compounds released by plants. **W**



Why are cats scared of cucumbers?

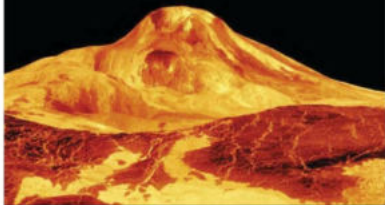
@KEEPPROMISES_X, VIA TWITTER

Videos of cats jumping out of their skin when finding themselves in the presence of a cucumber have been doing the rounds online for a while now. Cats are hypersensitive to their surroundings, so it's the sudden appearance of a random object that has them spooked. Cucumbers also look quite snake-like on first glance, so this may be why this vegetable provokes such an extreme reaction. Please don't try this at home, though – it's stressful for the cats! **cc**

Could climate change turn Earth into Venus?

ANDREW KEMP, CHESHIRE

Venus's atmosphere is 96 per cent carbon dioxide, driving a powerful greenhouse effect that creates surface temperatures of up to 450°C. Earth's atmosphere, on the other hand, currently contains 0.04 per cent carbon dioxide, with trace amounts of other greenhouse gases. While greenhouse gas concentrations have been rising as we burn fossil fuels, they are still far from Venus's levels. Even if we were to burn all available fossil fuels, the likely impact on our planet's temperature would be a 10°C rise. This may seem modest by Venus's standards, but it would be enough to cause a sea level rise of more than 50 metres. **APC**



THE THOUGHT EXPERIMENT

WHAT IF HUMANS HAD CHLOROPHYLL IN THEIR SKIN?



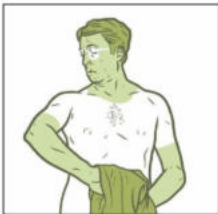
1. WE'D STILL NEED TO EAT

Photosynthesis is only 3 to 6 per cent efficient. If you stood naked outdoors all day, you would generate less than 240 calories – about three chocolate digestive biscuits' worth. If you weren't eating anything to supplement this, photosynthesis wouldn't even be enough to offset the heat your naked body would lose. You'd die of hypothermia before you hyped.



2. WE'D STILL NEED OXYGEN

Plants generate all of the oxygen they need as a by-product of their own photosynthesis. But since you'd need to eat extra food to power your more active metabolism, you'd also need to breathe extra oxygen in order to convert all of that food into energy. Photosynthesis would let you lower your breathing rate by 10 per cent at most. Photosynthetic astronauts would still need oxygen tanks.



3. WE MIGHT NOT EVEN BE GREEN

Most plants need light to synthesise chlorophyll. If humans used the same mechanism, our skin would only be green where it was exposed to the Sun. Office workers and many people in northern latitudes probably wouldn't get enough sunshine to tint their skin more than pale yellow, except on their face and hands. Those working rolling shifts might cycle between green and white.

How was the length of a second first calculated?

RORY EATON, BRIGHTON



Ancient civilisations like the Babylonians focused on the major time units of years, days and hours, whose relative lengths they determined using astronomical observations. But the invention of the first practical clocks in medieval times allowed finer division. These were named in Latin *pars minuta prima* – 'the first very small part', now called the minute; and *pars minuta secunda* – 'the second very small part', now called the second. Following the tradition set by the Babylonians, these divisions were expressed using the sexagesimal system, a form of counting based on units of 60. Using this, the length of a second became a sixtieth of a sixtieth of an hour, leading to its definition as 1/3600th of an hour. **BM**



Can marine animals get the bends?

ELEANOR CALDWELL, LONDON

In scuba divers, the bends is caused by ascending too quickly. Nitrogen dissolved in the bloodstream can form bubbles before the gas has had time to return to the lungs, causing pain and tissue damage. Marine animals, however, don't normally suffer from this condition. To find out why, scientists recently put a dead dolphin and seal in a pressurised chamber and carried out a CT scan. They found that the marine mammals' lungs were separated into two regions: one filled with air, one collapsed. As the lung is collapsed, so too are the little air sacs inside the lung, where gas exchange takes place. It's thought that the blood flows mostly through the collapsed part of the lung, minimising the amount of nitrogen that can enter the animal's bloodstream, while still allowing some oxygen and carbon dioxide to pass. **NS**

CITIZEN SHUTTERSTOCK

Why do we find puppies so cute?

ARNOLD HOPPER, SWANSEA

With their big, round eyes, button noses and large heads, puppies share many of the same physical characteristics as human babies. And like babies, as well as kittens, teddies and many cartoon characters, puppies provoke in us an automatic 'cute response'. They grab our attention, we enjoy looking at them and, at a neural level, they trigger activity associated with reward and also compassion and empathy. In humans, and other animals, this response is an evolved, innate behaviour that motivates adults to look after helpless infants, and to be more sensitive to their needs and feelings. It makes sense, then, that a recent study found that puppies reach peak cuteness at eight weeks of age, just the time when their canine mothers leave them to fend for themselves. **G**



Why do British people seem to lose their accents when they sing?

ELLA, CALIFORNIA

It's partly that many of the distinctive characteristics of an accent aren't reproduced well when you sing. Vowel sounds get stretched, and the precise articulation of the consonants is lost. The result is a neutral baseline accent that sounds vaguely American. Most of the British artists who keep a noticeable accent have a more spoken, less melodic delivery. Think of Ian Dury, or the UK grime scene. But the Americanised accent is also partly a cultural expectation for certain musical genres, such as R&B or mainstream pop. Some bands do retain a strong regional accent, though – The Proclaimers, for example. **W**

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Unlike many Brits,
Ian Dury retained
his iconic accent
when singing



Why are some materials magnetic?

AHMED ZEB KHATTAK, PAKISTAN

It's the result of the motion of electrons inside atoms. When electrons move through a wire, the resulting current generates a magnetic field. Electrons inside atoms are also moving: they orbit the central nucleus of atoms, and spin on their axes. In most atoms, the resulting magnetic effect is weak. But in some atoms – like those of iron – a kind of subatomic force makes the spins of electrons of neighbouring atoms line up. This allows their individual magnetic fields to combine together, producing a magnetic field that extends beyond the atoms. **RM**

What causes bath bombs to fizz?

LAUREN KATHLEEN MAHANEY, TENNESSEE

Bath bombs fizz when water triggers a reaction between an acid and a neutralising substance known as a 'base'. Many bath bombs contain citric acid, as found in citrus fruits, and sodium bicarbonate, which is a weak base. The dry chemicals are stable, but in water they react together to produce carbon dioxide bubbles (fizz) and, as a by-product, sodium citrate salt. The reaction helps to break up the bath bomb, releasing fragrances, detergents and oils. **ED**



...I DON'T GET ENOUGH SLEEP?

Sleep is not just a passive rest. Your body uses this downtime to perform essential repair and growth, and short-changing yourself at night has serious consequences for your health. Studies have found that chronic sleep deprivation can double your risk of fatal cardiovascular disease, suppress your immune system and make you 30 per cent more likely to become obese. Overall, those who regularly get less than five hours of sleep per night are 15 per cent more likely to die in any given year than a person who has all the same health risk factors apart from the sleep deficit.



1. Bags under your eyes

Levels of the stress hormone cortisol increase, which raises blood flow to the skin. This shows as dark, puffy patches under your eyes where the skin is thinner than elsewhere on the face.



2. Loss of perspective

MRI scans show that the amygdala region of the brain, which regulates emotion, tends to overreact to negative events when you are sleep-deprived. Bipolar disorder is also linked to sleep disruption.



3. Diabetes

You metabolise glucose more slowly when you are tired. This increases your risk of developing type 2 diabetes.



4. Heart disease

The complex interaction of stress hormones, increased blood pressure and reduced glucose metabolism increases your risk of heart disease.



5. Obesity

Raised ghrelin levels (the appetite hormone) stimulate you to eat up to 25 per cent more, and you will tend to prefer carbohydrate-rich foods.



6. Muscle aches and twitches

Neurotransmitters in your nerve synapses build up over the day's activity. Without enough sleep to regulate this, your muscles will twitch erratically.



Is it possible to get pregnant when you're already pregnant?

ASHLEY MARTIN, HAMPSHIRE

Getting pregnant while already pregnant is called superfetation. It's been reported in mammals, including mice and rabbits, and there have been a handful of possible cases in humans. In 2017, a US woman acting as a surrogate mother was reported to have discovered that one of the twins that she was carrying was in fact her biological son. She had apparently become pregnant roughly three weeks after her surrogate conception.

For superfetation, a woman has to ovulate again after becoming pregnant. This is rare because hormonal changes after conception usually prevent the ovaries from releasing another egg. What's more, a mucus plug forms in the cervix during pregnancy, which should prevent sperm from swimming up. **EN**

IN NUMBERS

24,000,000

The number of slices of bread thrown away every day in the UK, according to Waste and Resources Action Programme (WRAP).

44

The length, in kilometres, of a cat-proof fence that has been built in Australia to protect native marsupials and birds.

WHAT IS THIS?

Dwarf frog derrière

While it might look like a pair of eyes glinting at you, this is actually the inflated backside of a Cuyaba dwarf frog. The amphibian, which is native to Brazil, Paraguay and Bolivia, pumps up its rump when threatened, in the hope that those huge eyespots will scare predators away. If that doesn't work, the frog will secrete a toxic and nasty-tasting substance that should allow it to make its getaway.



WHO FIRST CLAIMED?

PLANETS GO ROUND THE SUN

ARISTARCHUS
OF SAMOSNICOLAUS
COPERNICUS

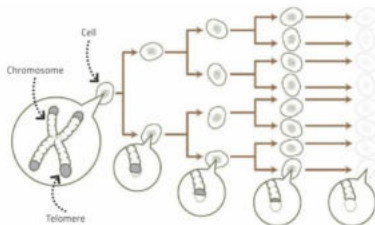
The idea that the Sun is at the centre of the Solar System seems to fly in the face of the 'obvious' fact that it moves across the sky, along with all the other planets. Combine that with religious doctrine about the Earth being the focus of everything, and it's small wonder that the so-called 'heliocentric theory' only became established in the 16th Century.

Credit for that goes to the Polish astronomer Nicolaus Copernicus, whose treatise *On The Revolutions Of The Heavenly Spheres* (1543) argued that the Sun's motion was the result of the Earth spinning on its axis. Even so, Copernicus kept the ancient notion of the Solar System being made up of concentric spheres, within which the planets moved on gear-like 'epicycles'.

Nor was Copernicus the first person to put the Sun at the centre of it all. Around 1,800 years earlier, the Greek astronomer Aristarchus of Samos had also proposed the same idea. In common with some earlier scholars, he argued that the Earth rotated on its axis, but he also realised that this raised the possibility that the Sun's apparent movement across the sky might be an illusion. Unfortunately for Aristarchus, he was so far ahead of his time he was unable to provide any clinching evidence. **BM**

Is there a theoretical upper limit to human life?

LEWIS RYLANDS, LIVERPOOL



Most of the cells in your body have a natural lifespan, called the 'Hayflick limit'. This is because chromosomes have biological hookends, called telomeres, that get shorter each time the cell divides. When the telomere shrinks past a certain point, the cell won't divide any more and eventually dies. Statistical projections, based on the typical rates that our different cells divide, suggest an upper limit to our lifespan of around 120. This corresponds pretty well with what we observe: the longest lived person was Jeanne Calment, who died aged 122, and only a handful of others have made it past 110.

Cell lifespan isn't fixed, though. When organs are transplanted into a younger body, the cells in the older organ live as long as the body into which they are transplanted. This may be because their telomeres grow longer again. Skin cells, sperm and some white blood cells can do this using the enzyme telomerase, and manipulating telomerase levels for other cells in lab animals does sometimes extend their lifespan. But it also seems to increase their cancer rates. In fact, there is evidence that cell ageing mechanisms evolved to protect multicellular organisms from cancer, so mortality might be inescapable. **EW**



Does it take more effort to swim in the deep end of a pool than the shallow end?

KEVIN WARD, STROUD

When swimming, water generates drag forces from three sources: friction from the 'stickiness' of water, waves created on the surface, and resistance to pushing through the water. Unless the water is so shallow that the chest

of the swimmer takes up a sizeable fraction of the total depth, these sources of drag are the same for shallow or deep water, so that swimming will require the same amount of effort. **BM**

WHAT SHAPES OUR MUSIC TASTE?

We teamed up with the folks behind BBC World Service's *CrowdScience* to answer your questions on one topic. You can tune in to *CrowdScience* every Friday evening on BBC World Service, or catch up online at bbcworldservice.com/crowdscience

Can you train your brain to like different music?

You might always hate free jazz, but research by neurophysiologist Prof Alice Mado Proverbio has shown that the more we listen to complex music (Stravinsky's *The Rite Of Spring*, for example), the more we start to appreciate it. Meanwhile, if you want to pass on your unconventional music taste to the next generation, the trick is to influence young minds. Prof David Hargreaves at the University of Roehampton uses the term 'open-mindedness' to describe how young children are more able to listen to unusual forms of music – a skill that drops off at around the age of 10 or 11.

Why do people have such different music tastes?

Across all cultures, we seem to like certain note combinations and respond similarly to certain clapping patterns. But when you unpick music at more complex levels, divisions emerge. Dr Catherine Loveday, a cognitive neuroscientist at the University of Westminster, likens our music taste to our comedy taste. The more complex the comedy, the more it relies on the audience knowing the cultural context. Similarly, our music preferences are shaped by the people and groups we identify with – our culture, in other words. But it's also to do with our individual makeup. A 2015 study at Cambridge University found that our music taste is linked to our 'thinking style' – in essence, whether we're more emotionally- or analytically-minded.



Why do we get so nostalgic about music?

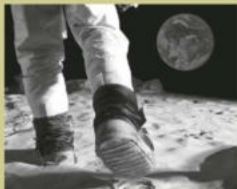
It's all to do with the 'remiscence bump'. Psychologists have shown that we tend to remember more events from our teenage and early adult years, and that our favourite music also tends to be from this time. It's during these years that our identities are forming, and the songs that accompany our adolescent experiences leave a lifelong emotional imprint in the brain. Research at Cambridge University in 2013 confirmed that we place less importance on music as we get older, and that the music we do seek out tends to be less intense and more 'sophisticated', such as jazz and classical.



Marnie Chesterton is the presenter of *What Shapes Our Music Taste?*, an episode of *CrowdScience* that aired in June. It's now available to stream online.

How long would it take an astronaut to walk around the Moon?

THEODORE BARKAS, ATHENS, GREECE



The Apollo astronauts managed a walking speed of about 2.2km/h, which is around half of the typical speed on Earth. This is partly because the Moon's lower gravity gives you much less traction on the ground, but the Apollo spacesuits were never really designed with long-distance hikes in mind. A 2014 NASA study looked at the theoretical maximum walking speed on the Moon, finding that you could walk at 5km/h before you would need to break into a loping run. At this speed, you would travel the 10,900km circumference of the Moon in 91 days of non-stop walking. **EW**



Are VR headsets bad for your health?

JON SHIELDS, WELLS

Virtual reality (VR) is really taking off, with over 10 million sets being sold globally last year. But whether they're sophisticated headsets or cardboard adapters for smartphones, they've become the focus of health concerns. The most obvious risk involves injuries caused by blundering into real objects while immersed in VR. But there's growing concern about more subtle health effects. Many people report headaches, eye strain, dizziness and nausea after using the headsets. Such symptoms are triggered by the VR illusion, which makes the eyes focus on objects apparently in the distance that are actually on a screen just centimetres away.

Known as vergence-accommodation conflict, this is now under investigation for its long-term effects, especially among children. A recent study by researchers at Leeds University found that just 20 minutes exposure to VR could affect the ability of some children to discern the distance to objects. There are also concerns that regular use of VR could accelerate the global epidemic of myopia – short-sightedness – which is predicted to affect one in three of the world's population by 2020.

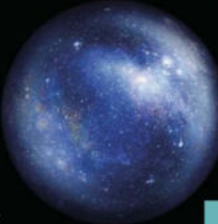
Manufacturers of VR headsets are racing to solve the problem as it potentially poses a major threat to the widespread adoption of the technology. **BM**

QUESTION OF THE MONTH

What is the Universe expanding into?

TOBY GRAHAM, SHREWSBURY

Presently we do not know (and may never know) whether the Universe is infinite or not. If the Universe is infinite, then it can simply keep expanding without getting any bigger (since you can't get bigger than infinity). It's therefore not expanding into anything. On the other hand, if the Universe is finite in extent, this question becomes impossible to answer, since – being part of the fabric of the Universe ourselves – we have no way of looking outside it. **AGC**



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NEXT ISSUE:

Why do we sweat when anxious?
Could a pH greater than 14 exist?
Why do we get freckles in the Sun?

Email your questions to questions@sciencefocus.com or submit online at sciencefocus.com/qanda



WHY DOES SAND GO DRY WHEN YOU STEP ON IT?


There's something about walking barefoot along a sandy beach, just above the line of the waves, that is always special.

Being the first to step on newly smoothed sand is liberating, and it's as though you're making a fresh start with every step. But something odd is happening. As each foot presses on the damp sand, you see a circle of lighter coloured dry sand spread out around it, which shrinks back as your foot lifts off. It's weird, because you might expect that pushing the sand downwards would allow water to flood in. If anything, you'd expect the sand near your foot to get wetter, not drier. But sand is strange stuff, and that dry layer is showing you one of its oddest properties.

Look at a handful of sand, and you'll see that it's made up of tiny fragments of rock and shell in a range of shapes and colours. The shapes don't fit snugly together, so even in tightly packed sand, the spaces between the grains account for around 40 to 50 per cent of the volume, and those spaces are filled with air or water. The rough surfaces of the grains lock them together, so the beach is solid enough to walk on.

When you step, your foot presses down on this interlocked pile, and this is where things get interesting. The tightly packed solid grains can't squish downwards – there's nowhere for them to go. But the area around your foot isn't being pressed. The sand can't be squashed, but it can still move out of the way by sliding diagonally. Therefore, as the sand right underneath your foot moves downwards, the sand to the side of that slides round and up to the sides. The key here is the process of nudging sideways – layers of interlocked grains need to move over each other, ever so slightly. But these grains are efficiently packed – each one sits in a small hollow made by its neighbours. Imagine a flat layer of apples in a grocery shop box, with just one apple on top. The apple starts off by sitting in a dimple in the layer below. You can push it sideways, but in order to move, it must rotate and lift up as it rolls over one of the apples below. The same thing is happening in the sand. Under your feet as you walk, hundreds of thousands of sand grains are pivoting over each other as the sand slides out of the way. As the grains roll out of their hollows, they get further apart overall.

This is the fundamentally weird thing about sand – as you force it to slide sideways like this, it increases in volume. As you step on it, the sand beneath your foot takes up more space, not less, and the expansion happens beneath that circle of lighter sand that you can see spreading outwards. The water drains downward into the larger gaps below, leaving a much drier top layer. Once you lift your foot off, everything rotates back and the water comes back to the surface.

So if you're lucky enough to spend some time wandering along a beach this summer, take a moment to watch your steps, and to poke the sand and experiment. You never have to look far to find a fascinating piece of physics, because you live every day in the best toy box we have, and it's all right there in front of you. All you have to do is take a moment to notice, and then let yourself play. 



DR HELEN CZERSKI

Helen is a physicist and BBC presenter. Her latest book is *Storm in A Teacup* (£18.99, Transworld).

OUT THERE

WHAT WE CAN'T WAIT TO DO THIS MONTH

SUMMER 2018

EDITED BY HELEN GLENNY

01

INVISIBLE WORLDS
EDEN PROJECT, CORNWALL
OPEN NOW
EDENPROJECT.COM

MARVEL AT THE INVISIBLE

This summer, the Eden Project's new permanent exhibition called *Invisible Worlds* examines the parts of the planet that exist beyond our senses. A centrepiece of *Invisible Worlds* is Infinity Blue, which is an immersive, 20-tonne sculpture that celebrates cyanobacteria. Why should we care about them? Well, they are the organisms that gave us a living, breathing world when they started to photosynthesise around 2.4 billion years ago, releasing free oxygen into Earth's atmosphere and changing the nature of our planet.

Infinity Blue features 32 cannons that project scented vapour rings, which were developed to represent the aromas of the primordial world. To create the smells, sculptors Studio Swine collaborated with Paris-based perfume house Givaudan.

"Infinity Blue gives physicality to the invisible elements our existence depends on: our breathable atmosphere, microbial life and deep time," says Studio Swine.

Elsewhere, you can go on safari to discover curious microbes and what they do; you can become part of the Eden Project's digital installation and watch as matter flows in and out of your body; and then you can head outside to travel through Eden's Outdoor Gardens and learn what's in the 20,000 breaths we take every day.

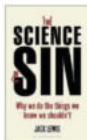


02

THE SCIENCE

OF SIN

BY JACK LEWIS
OUT 12 JULY 2018
(£16.99, BLOOMSBURY
SIGMA)



UNDERSTAND SIN

Neurobiologist JACK LEWIS talks to HELEN GLENNY about sin, why we should resist it, and the wacky experiments that test our ability to behave

What are the seven deadly sins, in scientific terms?

They're seven antisocial impulses, and acting on them tends to break social connections with your community. Christianity says you'll go to heaven if you avoid these vices, but I argue that you'll have better relations with other people. That's important because becoming lonely and isolated from your community has severe negative implications on your physical and mental health.

Can you tell if someone's sinning by looking at their brain?

The dACC, or dorsal anterior cingulate cortex, has been implicated in a broad spectrum of antisocial behaviours, and the first critical link in the chain came from looking at narcissists. Researchers simulated social exclusion with a virtual game where you're passing a ball with two friends who then start passing the ball exclusively between themselves, so you feel that horrible feeling of being left out. Activity in the dACC was greater in narcissists experiencing that social pain than in non-narcissists.

Then another study showed that the degree of someone's narcissism impacted the desire to take revenge in that sort of situation, but only if that social rejection led to an increase in dACC activation.

When I went on and looked at other sins, this area kept cropping up. It lights up when people are feeling physical pain, social pain or processing conflict.

Which other sins caused the dACC to activate?

It cropped up in envy, wrath, lust and the neuroeconomics of greed. Across hundreds of financial exchange experiments, whenever your slice of the pie is smaller than the other person's, the dACC lights up. There's also an amazing bunch of experiments about wrath. Psychologists wire up two people so

one can electrocute the other, then the person who got zapped can zap the other one back. But everyone believes the electric shock they received was more painful than the one they inflicted, so the participants keep cranking up the intensity. The degree to which the participant cranked up the electric shock was proportional to the degree of activation in the dACC. That's another suggestion that this brain area could explain, or even be the root cause of the urge to inflict antisocial behaviour on someone.

Can we turn down activity in the dACC to help us avoid sinning?

Researchers have looked at Buddhist monks doing an experiment where there's a pot of money, and one person can decide how to split it. If the other person isn't happy about how much they're offered, they can reject the offer and no one gets any money. If someone offers 30 per cent, taking 70 per cent for themselves, most people turn it down because they're resentful that the person has proposed such an unequal split. But Buddhist monks accept that deal, and the neural correlates of emotional distress aren't there.

What can neuroscience tell us about sin?

When people do things they shouldn't, it's usually caused by emotional suffering. The best example to support this idea is that the intensity of social pain experienced by narcissists is mirrored in the strength of their dACC activation, which is in turn proportional to the extent of the punishment inflicted on whoever caused them to suffer feelings of rejection in the first place.

Feeling connected to your community is essential to your health, and if you want everyone to stay connected, you need to provide as much help as possible to rein in these antisocial tendencies.

AUTHOR'S BOOKSHELF

Three books that inspired Jack Lewis while writing *The Science of Sin*



THE BELIEVING BRAIN

BY MICHAEL SHERMER
(£8.99, LITTLE BROWN
BOOK GROUP)

My understanding of why belief in the supernatural is inevitable in humans is grounded on the evidence presented in this book.



THE BRAIN THAT CHANGES ITSELF

BY NORMAN DOIDGE
(£10.99, PENGUIN)

This is a masterpiece in how to get non-scientists interested in, excited by, and motivated to act upon the incredible potential of every human brain.



RELIGION FOR ATHEISTS

BY ALAIN DE BOTTON
(£10.99, PENGUIN)

This book inspired my conviction that we should retain the community-building aspects of religion, no matter our beliefs.

FIND OUT MORE

1 Listen to our interview with Jack Lewis on the Science Focus podcast. Visit sciencefocus.com/sciencefocuspodcast

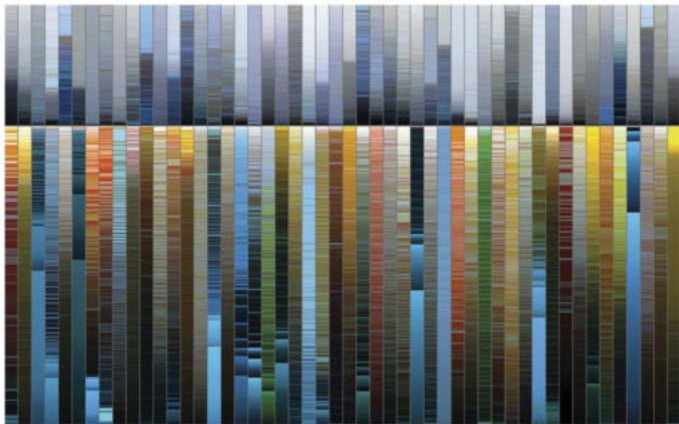
03

LIFE AT THE EDGE
SCIENCE GALLERY, DUBLIN
UNTIL 30 SEPTEMBER 2018
DUBLIN.SCIENCEGALLERY.COM

EXPERIENCE THE EXTREME

Picture Antarctica. Wind rushing across swathes of ice and sea, with the occasional sprinkling of penguins, right? That's what the upper part of *Antarctica: A Chromatic Paradox*, by Skye Moret shows (pictured below). The lower part samples colours from underwater Antarctic photos, revealing the diversity of organisms we never see.

The image is part of *Life At The Edge*, an exhibition that explores extreme environments, from terraforming planets to geothermal vents. It seeks to explain why inhospitable settings spark our appetite for adventure, asks what we can learn from severe conditions, and explores the intersection of art, design, science and exploration.



04

**THE GENIUS
OF ACCIDENTS**
BBC RADIO 4
WEEK OF 24 JULY

CELEBRATE
ACCIDENTS

In 1989, scientists at pharmaceutical company Pfizer were looking for a treatment for angina, a condition that constricts the blood vessels in the heart. The drug they created, sildenafil citrate, didn't work for its intended purpose, but it did increase erections for the trial volunteers. Researchers realised that the drug opens the blood vessels in the penis, and the first erectile dysfunction treatment was created.

Science and innovation is riddled with accidents. Post-it notes, superglue and even nuclear fission didn't come about as the result of rigorous development or technical genius – they were invented by accident. In *The Genius Of Accidents* on BBC Radio 4, Adam Hart is exploring how much we owe to lady luck, to scientific carelessness, and marvellous mistakes.





05 LEARN THE SECRETS OF THE MILLENNIUM SEED BANK

**KEW SCIENCE
FESTIVAL**
WAKEHURST
21-22 JULY 2018

The Millennium Seed Bank in Wakehurst safeguards around 38,000 different species of plant from all around the world, making it an apt host for this year's Kew Science Festival, which has the theme of 'rare and threatened'. Here are three things we found out about the Millennium Seed Bank...

1. IT'S WHERE YOU'D WANT TO BE DURING THE APOCALYPSE

Whether it's WWII, nuclear catastrophe or natural disaster, if you were tucked away inside the Millennium Seed Bank, you'd likely survive it all. Its vault is flood-proof, bomb-proof and radiation-proof, and the photovoltaic panels on the roof provide enough electricity to power the freezers in the vault. It has the capacity to house 75 per cent of world's storable seeds, so once the planet was ready to inhabit again, you'd have a lot of planting to do.

2. IT SERVES AS A BACKUP FOR 80 PER CENT OF THE WORLD'S FOOD

That 80 per cent comes from just 12 crop plants, and the Millennium Seed Bank is building a store of the wild relatives of each of those in the Wild Species Seed Bank. For example, there are several wild relatives of rice that have characteristics that are useful for things like disease resistance, yield, and early morning flowering (so that flowers aren't affected by higher daytime temperatures). These traits aren't in domesticated species, but if needed, they can be put back in to domesticated crops to make them more resistant to a changing world.



3. IT HOUSES SEEDS THAT ARE ILLEGAL IN THE UK

Around 30,000 species of plants are protected by CITES, banning anyone from importing them into the UK. Mostly, these are endangered plants being protected against overexploitation through international trade, similar to how ivory is being banned to deter poachers. The Millennium Seed Bank is the UK's scientific authority for the trade in illegal plants, so if any come in to Heathrow, they end up at the Millennium Seed Bank's quarantine facility.

EXPLORE SEED PROTECTION AT KEW SCIENCE FESTIVAL'S POP-UP EVENTS

USEFUL SEEDS

Discover which plants are essential for the human race, and why we need to safeguard their future.

CRYO CORNER

Some species won't survive regular preservation techniques. Watch as scientists use ice-cream to explain how seeds can be conserved.



DNA FACTORY

Try your hand at extracting DNA from a strawberry, and learn exactly what DNA looks like.



NASA/JIM HARRIS

06

**MOON, MARS
AND BEYOND**
ROYAL INSTITUTION,
LONDON
17 JULY 2018, 7PM

ESCAPE EARTH

We've colonised this planet, so where to next? Al Worden was the command module pilot for Apollo 15, and became the senior aerospace scientist at the NASA Ames Research Centre upon his return to Earth, so he's well equipped to talk about where space exploration is headed. He's speaking to Chris Welch, Stuart Eves and Helen Arney about where we should inhabit next – arguing the case for the Moon, Mars or beyond.

LISTEN UP

Live in the countryside? Tied up in the evenings? Too busy simultaneously watching your children, roasting a chicken and painting the kitchen ceiling to go to any events? You need to get your science fix via a podcast! Here are our favourites:



SCIENCE VS

If you want to win dinner party debates, this is the podcast to try. The team are a

group of friendly fact-checkers who dissect fads and trends using scientific research. Whether you want the facts on climate change, nuclear war or circumcision, it's got you covered.



INVISIBILIA

This podcast examines the hidden forces that shape human behaviour,

such as beliefs, ideas, assumptions and emotions. The team tracks some fascinating case studies, like someone whose intense daydreaming interferes with real life, and a woman who feels no fear.



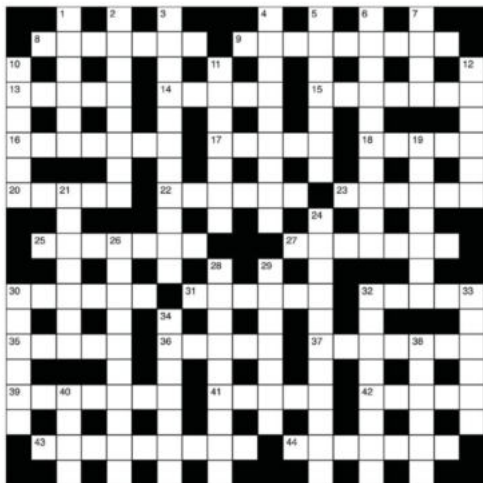
SCIENCE FOCUS PODCAST

Sure, we're biased, but we think this one's pretty good.

Each week a BBC Focus team member has a deep-dive chat with one of the brightest minds in science, technology and health, about the ideas and breakthroughs that influence our understanding of the world.

BBC FOCUS CROSSWORD

GIVE YOUR BRAIN A WORKOUT



DOWN

- 1 Shapely bend starts as a vitamin deficiency (6)
- 2 Sailor posted notes, as he's not there (8)
- 3 Drug makes Greek character stop with hesitation (4,7)
- 4 Prevent fellow getting cleaner (9)
- 5 Protestant bishop suitable first (7)
- 6 80s pop star in Spain is unbreakable (10)
- 7 In and around a former empire (4)
- 10 Become a prisoner as a warning (6)
- 11 This country finds changes are in another (7)
- 12 Friend to get married, back to show some neck (6)
- 19 In charge during advance on old artist (7)
- 21 Let up and come about phone lines (7)
- 24 Moving study is by nomadic arrangement (11)
- 26 Tan, darling, that's sweet (5,5)
- 28 Month gone by, getting professor round shape (9)
- 29 Yours truly gets terribly stale in race (7)
- 30 Victor to learn dancing like spring (6)
- 32 British soldier returns tree to New York (3,5)
- 33 Craft connection to fade audibly (3-3)
- 34 Wails about getting greeting in another language (7)
- 38 A lease includes German silver (6)
- 40 Regarding engineers starting at home (2,2)

ACROSS

- 8 Sunday taxi drivers reject ombudsman's third complaint (7)
- 9 Nice and complicated about the Spanish plant (9)
- 13 Lofty address has a sinister sound (5)
- 14 Beer with new king in joint (5)
- 15 Drums tell story about island doctor (7)
- 16 Shout about last form of glass (7)
- 17 Answer, say, is patronage (5)
- 18 Plane forced to land (5)
- 20 Fool concerning something explosive (5)
- 22 Dogtooth (6)
- 23 Temporary setback of the diaphragm (6)
- 25 Weep when fat (7)
- 27 Daughter is to relax due to illness (7)
- 30 Reject circling cape on right flight path (6)
- 31 Weakling and bully on a road (6)
- 32 Dismissal gets society to improve (5)
- 35 Old Italian-style manor (5)
- 36 Wife to warm up some cereal (5)
- 37 Temporarily free programs for equine attire, say (7)
- 39 Every character upsets him, taking Utah angle (7)
- 41 Fool has morning tea (5)
- 42 Happy endings initially gratify my stunted character (5)
- 43 American woman to appear on a carpet (9)
- 44 Diamonds come down in the country (7)

ANSWERS

For the answers, visit bit.ly/BBCFocusCW. Please be aware the website address is case-sensitive.



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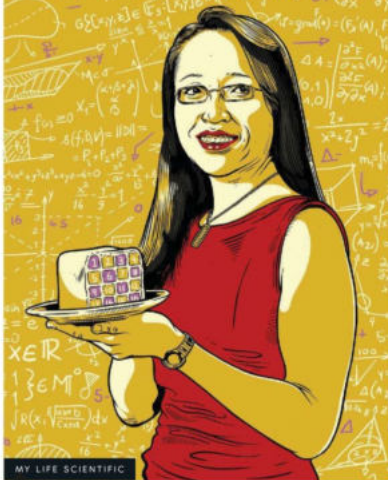
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MY LIFE SCIENTIFIC

Dr Eugenia Cheng

Mathematician and pianist Eugenia Cheng talks to Helen Pilcher about maths, music, cake, and why it's good to get things wrong

Eugenia runs the Undertube, an informal classical music salon in Chicago, where musicians can just turn up and perform.

What do you do?

I teach, talk and write about maths, and research abstract algebra. I'm also on a mission to rid the world of maths phobia.

Why are people maths phobic?

Part of the problem is the way maths is taught. So much is about following rules and getting the right answer, but this can be confining. If kids get things wrong it can make them feel stupid, so it's off-putting.

How should maths be taught?

We should teach maths so it's less about getting the right answer, and

more about investigation and discovery. Maths isn't just about numbers, it's about thinking. I teach maths to university art students by getting them to cut stuff out and stick it together. They discover that triangles are a good shape for covering surfaces. That's quite a profound mathematical insight. In my ideal scenario, the education system would focus less on test results and trust teachers to know how the students are doing. Food can be motivating too.

Mmm... food. The maths of cake?

Why not? Food can be really

motivating. Maths is like cooking. You add different things together and see what you get. I use Battenberg cake when I'm teaching group theory to my second year maths students because its structure is a piece of high level maths.

How do you relax?

I'm a classically trained pianist, so I play the piano. I play Bach every day because it aligns my brain and satisfies my soul, but I also enjoy Debussy because it's less technically challenging but musically fulfilling.

Aren't maths and classical music both a bit highbrow?

People often think that unless they've studied them and passed tonnes of exams, these subjects are off limits. That's a shame. You don't need to be able to do maths or play music in order to appreciate it, just like you can go into a museum and appreciate paintings without being an artist. I try to bring classical music to a wider audience.

Are maths and music linked?

They're both about structure. You need to understand the internal structure of a complicated piano piece or mathematical problem in order to get your head around it.

Any bad habits you'd care to admit?

I'm a spectacular procrastinator. There are also times when I get stuck at work and the only thing that unsticks me is having something to eat. I find that really annoying.

Where is your favourite place?

I love being by the sea. I grew up in Brighton so I have an affinity to pebble beaches. I also love the beach in Nice, where I worked for a year. It's like Brighton, but warmer. ☺

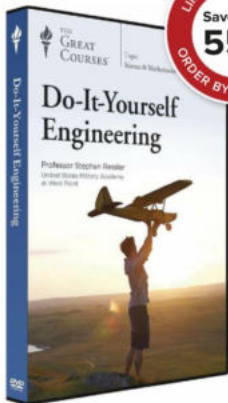
Dr Eugenia Cheng is scientist in residence at the School of the Art Institute of Chicago. Her new book, *The Art Of Logic: How To Make Sense In A World That Doesn't* (£14.99, Profile Books) is out now.

DISCOVER MORE



To listen to an episode of *The Life Scientific* with Dr Eugenia Cheng, visit bit.ly/eugenia_cheng

NEXT ISSUE: ALICE ROBERTS



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